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# China Report

SCIENCE AND TECHNOLOGY

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10 December 1985

## CHINA REPORT

### SCIENCE AND TECHNOLOGY

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## NATIONAL DEVELOPMENTS

## SONG JIAN ON SCIENCE, TECHNOLOGY SURVEY

OW160535 Beijing XINHUA Domestic Service in Chinese 1419 GMT 14 Nov 85

/Text/ Tianjin, 14 Nov (XINHUA)--The national meeting on training for the general scientific and technological survey concluded in Tianjin today. Song Jian, minister of the State Scientific and Technological Commission, delivered a speech at the meeting. He said: In order to ensure the healthy development of our economic structural reform, we must not only practice microflexibility but must also strengthen macrocontrol. To conduct a general scientific and technological survey is of great significance in helping to correctly exercise macrocontrol.

The major task in conducting a general scientific and technological survey is to collect basic data on China's actual strength and work conditions in science and technology so that such data may be used to help formulate scientific and technological policies.

Song Jian said: China lacks a complete statistical and monitoring system in the science and technology field. Therefore, it is unable to keep abreast with macroparameters changes, thus hampering the formulation of macropolicy decisions. He said: It will be dangerous if we do not solve this problem soon and if we blindly formulate and implement our policies. Therefore, the leading Group for Scientific Work under the State Council has decided to conduct a general, nationwide scientific and technological survey from this winter to next spring. He called on everyone to attach great importance to this work, gradually make it an important component of China's statistical system, and persistently carry out the survey and provide scientific data to the state to help formulate its macropolicy decisions.

Song Jian emphatically pointed out: The General Scientific and Technological Survey this time will involve more than 4,700 independent research institutions. Time is short, and our task is arduous. In addition, the people know little about the statistical system, and they lack experience in conducting a scientific and technological survey. We are sure to encounter some difficulties. He called on everyone to attach great importance to this work, join their efforts, and complete this capital construction project on the scientific and technological front with flying colors.

The national meeting on training for the scientific and technological survey began on 6 November. It was attended by more than 260 people from the departments concerned in 29 provinces, municipalities, and autonomous regions throughout the country.

## NATIONAL DEVELOPMENTS

### CHINA'S HYDROCRACKING TECHNOLOGY DESCRIBED

Shanghai HUAXUE SHIJIE [CHEMICAL WORLD] in Chinese Vol 26, No 7, 20 Jul 85 p 280

[Text] China's hydrocracking technology research began in the early 1950's and the first high-pressure hydrocracking facility went into operation in 1951, using as a feedstock, a light distillate from alkaline-treated shale to produce gasoline and kerosene. In the 1960's, new breakthroughs were achieved in the development relating to hydrocracking catalysts. In 1983, the first high-pressure hydrocrack facility entirely designed and built by Chinese came onstream at the Daqing refinery. In the late 1970's, four hydrocracker facilities were imported into China, two of them for the production of fuel oil and the other two for the petrochemical feedstock--naphtha. Out of these four units, two have been installed while the other two are still under construction. Furthermore, the Fushun Petrochemical Plant No 3 had built an additional hydrocracking unit plus two more medium-pressure hydrocracking units which are either in the design stage or under construction.

The hydrocracking facility at the Fushun Petrochemical Plant No 3 with an annual capacity of 400,000 tons is currently the largest and most technologically advanced facility designed in China. Construction was started in 1983 and completed in 18 months. In August 1984, it was successfully placed into operation on the first try. A large number of new technologies, new equipment and new types of instruments were incorporated into this facility so that its technological level is at about the mid-1970's world level. This is a big step forward in raising our hydrocracking technology.

The 800,000-ton-per-year hydrocracking facility at the Maoming Petroleum Co. started production in November 1982. By the end of 1983, it processed 490,000 tons of vacuum residuum, 7,000 tons of coking wax oil and produced altogether 470,000 tons of gasoline, kerosene, diesel oil and liquid hydrocarbon. Judging from the trial production runs, the quality of products is within the design specifications. The liquid recovery of the facility reaches 35.6 percent and light oils recovery 94.3 percent, which are 12.1 and 14.3 percent higher, respectively, than the catalytic cracking process.

The second phase of the 900,000-ton-per-year combined facility for aromatics at the Chemical Plant No 1 of the Shanghai Petrochemical Complex consists of 23 units for hydrocracking, rearrangement, extraction, disproportionation, isomerization, adsorptive separation, etc. is now completed. With the exception

of the disproportionation unit, all performed successfully on the trial runs and produced on-specification p-dimethylbenzene. The contractor of the project is the Sony Corporation of West Germany. The patented technology of the Union Oil Company [of California] of the United States has been adopted for the hydrocracking unit. This facility uses straight-run vacuum gas oil as a feedstock and employs a series of single-stage steps where exhaust end oils are continuously recycled through the hydrocrack process to produce the target product--heavy naphtha--as the feed material for subsequent rearrangement processing. The heavy naphtha produced is then converted through consecutive rearrangement units and followed with processing in the aromatics unit to form the final product, p-dimethylbenzene. It is designed to process 900,000 tons per year of straight vacuum gas oil to produce 552,000 tons per year of heavy naphtha.

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CSO: 4008/1081

NATIONAL DEVELOPMENTS

NATION NOW PREPARED TO SELL LAUNCH VEHICLES, INSURE SAME

OW261114 Beijing XINHUA in English 1059 GMT 26 Oct 85

[Text] Beijing, 26 Oct (XINHUA)--China is to put two types of vehicles for launching satellites--"Long March-2" and "Long March-3" rockets--into international commercial service.

This was announced by Li Xue, minister of astronautics, here today. He said this in an interview with XINHUA following the recovery of a scientific exploration and technical experiment satellite launched by a "Long March-2" rocket on Monday.

China launched an experimental telecommunications satellite in April of last year, using a "Long March-3" rocket.

He said, "our launch vehicles shall enter the international market since they have reached the mature stage technically."

Minister Li said the most recent launching was the seventh time in succession when a "Long March-2" was used successfully to send a satellite into orbit. This shows that the rocket is reliable and capable of sending a satellite into orbit with precision.

The minister said the "Long March-2" is a large two-stage liquid rocket developed in the mid-1970s. It has the capability of putting a satellite of about 2 tons into required near-earth orbit.

With regard to the "Long March-3" rocket, the successful launching of China's experimental telecommunications satellite into geostationary orbit shows that China has mastered the technology to put a satellite into geostationary orbit.

China has two launching centers--one in Jiuquan, Gansu Province, for launching satellites into near-earth orbits, and the other in Xichang, Sichuan Province, for launching geostationary orbit satellites. They can provide good launching service and early stage supporting service.

Meanwhile, China has established a measuring and controlling network with its center in Xi'an. It includes ocean-going measuring ships.

When asked about economic insurance in launching satellites, the minister answered, "the Chinese People's Insurance Company will provide economic insurance at preferential international prices if a foreign customer requests launching service."

He said, "we have already declared to the world that we will provide preferential treatment to customers, and we will also be responsible for training technical personnel."

/9604

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## NATIONAL DEVELOPMENTS

### NATION'S NUCLEAR INDUSTRY SERVES BROAD RANGE OF CUSTOMERS

OW041326 Beijing XINHUA in English 1249 GMT 4 Nov 85

[Text] Beijing, 4 Nov (XINHUA)--China is one of the five leading countries in the world boasting a relatively complete system of nuclear science, technology, and industry.

China started its nuclear industry from scratch in 1955. During the [last] 30 years, nuclear technology has been incorporated into all sectors of the national economy.

Six geological prospecting bureaus have been set up to explore for uranium resources. Verified reserves of that element are sufficient to fuel nuclear power plants with a generating capacity of 15 million kilowatts for the next 30 years, in addition to meeting the demands of military use.

In early 1964, a nuclear fuel production plant went into operation. In October of that same year, China successfully conducted its first atom bomb test and exploded its first hydrogen bomb in June 1967. Nuclear power devices for submarines were subsequently developed. China's military forces have been equipped with nuclear weapons.

The peaceful use of nuclear energy and technology has promoted the development of new branches of science, technology and industry, thus contributing to the development of the national economy. China has built 10 nuclear reactors including its first high-flux engineering test reactor that went on stream in 1980.

The major buildings of the Qinshan nuclear power plant in Zhejiang Province, designed and built by China, are now under construction. The plant, which will have a generating capacity of 300,000 kilowatts, is expected to go into operation in 1989. China plans to build several nuclear power plants and thermal nuclear power plants by the end of the century. Feasibility studies and designs are under way.

China's largest controlled nuclear fusion experimental device, the H1-1, went into trial operation in September 1984.



Nuclear radiation and isotope technology has been applied in medical research since 1965. Over 100 kinds of isotopes are in use in 800 Chinese hospitals and research institutes. Eighteen million people have been diagnosed or treated with isotope technology.

In agriculture, Chinese scientists have developed over 160 new plant strains using radiation technology. Achievements have also been made in using radiation to increase output of eggs, fish and shrimp and to control plant diseases, insect pests and food spoilage.

China has produced 20 kinds of high-molecular materials by means of nuclear radiation technology. Nuclear logging is an important technique now used in the continuous recording of drilling data in oil and coal prospecting and exploitation. Nuclear analysis and instruments are now widely employed in the textile, printing, papermaking, plastic, metallurgical, petroleum and chemical industries.

China's nuclear industry will develop further during the seventh 5-year plan period according to a Nuclear Industry Ministry official. Apart from national defence needs, the focus will shift to the economy and construction. The ministry will actively implement the policy of opening to the outside world and strengthen technical cooperation and exchange with member countries of the International Atomic Energy Agency.

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CSO: 4010/10

NATIONAL DEVELOPMENTS

BEIJING HOSTS INTERNATIONAL DATA-RETRIEVAL FORUM

OW212026 Beijing XINHUA in English 1505 GMT 21 Oct 85

[Text] Beijing, 21 Oct (XINHUA)--The 1985 Beijing International Symposium on Computerized Data Retrieval, sponsored by the Chinese Society for Scientific and Technical Information, opened at the capital's Science Hall today.

The main topic for discussion is the planning and design of a national computerized data-retrieval network, which has been listed as a key objective of the country's science and technology development program.

Seventy data specialists from Canada, China, Italy, Japan and the United States are presenting 16 papers at the 5-day conference.

The papers involve the establishment of data bases and networks, the structure and design of data bases, policies on information retrieval and Chinese character retrieval.

In recent years, China has stepped up efforts to computerize data retrieval. So far, China has established retrieval terminals at Beijing, Shanghai, Xian, Chengdu, Chongqing, Shenyang, Nanjing and Guangzhou, which are connected to three systems in Europe and the United States.

China has also imported 50 foreign tapes listing specialized information to provide selected dissemination of information (SDI) services to Chinese users.

Speaking at today's opening ceremony, Liu Zhaodong, general secretary of the Scientific and Technical Information Society, said the symposium would promote the development of computerized data retrieval in China, and expand international cooperation.

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## NATIONAL DEVELOPMENTS

### 'FUZZY' MATHEMATICS APPLIED TO VARIOUS DISCIPLINES

OW061258 Beijing XINHUA in English 1215 GMT 6 Nov 85

[Text] Guiyang, 6 Nov (XINHUA)--Fuzzy mathematics is being applied widely to meteorology, traditional Chinese medicine, pharmaceuticals, architecture and aviation in China, a meeting was told here recently.

The subdiscipline of mathematics, developed by American Professor L.A. Zadeh in 1965, was introduced to China in the 1970s. Using the theory, scientists in Beijing and Shanghai first developed computer programs for diagnosis simulating methods of noted doctors of traditional Chinese medicine.

A paper entitled, "Fuzzy Classification of Acute Poisoning," put forward by a scientist from Guizhou Province, attracted the attention of foreign experts at an international symposium held in Hawaii last year.

Meteorological departments across China have held training courses in fuzzy mathematics and the subdiscipline has been used in weather forecast, climate zoning and agricultural research.

China has also adopted fuzzy mathematics to seismology. The results aroused the interest of foreign experts at an international symposium on seismic engineering held in Beijing in September.

Among the 160 participants at the recent national meeting, 57 are under 30 years of age. Zhang Hongmin, 26, has developed an artificial intelligence system to diagnose aeroplane engine defects, which has raised the accuracy of such inspections from 60 to 78 percent. His thesis will be presented at an international symposium on aviation in London next year.

Theoretically, Chinese scientists have developed fuzzy imbedding theory, fall-shadow of fuzzy set and random set and mesomeric mathematics.

A magazine, FUZZY MATHEMATICS, has been published by the Fuzzy Mathematics Society set up in 1983, and colleges and universities have opened courses in the subject.

Chinese scientists have given courses on fuzzy mathematics in the United States, Japan, France and Belgium. Among the collection of papers delivered at an international meeting held in Spain earlier this year, one fourth were contributed by Chinese scholars, according to the national symposium.

NATIONAL DEVELOPMENTS

STATUS OF QUALITY CONTROL SINCE 1978

Beijing ZHILIANG GUANLI [QUALITY CONTROL] in Chinese No 10, 18 Oct 85 pp 5-13

[Article by Yu Meifen and Chen Xiuyun, China Quality Control Association, Beijing, and Yan Renwei, East China Institute of Textile Science and Technology: "An Analysis of the Present Situation in the Quality Management of China's Industrial Enterprises"]

[Text] Abstract

This article makes a survey of the situation in the total quality control implemented in China since 1978, and, for the first time, using minicomputer to store the information data of the present situation in the quality management of China's industrial enterprises. Through statistics and analyses, the present situation in China's quality management is relatively and objectively analyzed and the relevant measures that should be adopted in order to launch the total quality control much better are preliminarily inquired into.

Raising of the Question

More than 6 years have lapsed since the total quality control was first implemented in China's industrial enterprises under government leadership in 1978. From giving publicity, making experiments to gradually implementing, activities of total quality control have been launched to varying degrees in nearly 35,000 enterprises up to the present. After the implementation of total quality control, some of the enterprises have their qualities and capabilities of market competition raised, with their production enhanced quickly as well as much better economic results; but there are still a lot of enterprises finding it is hard to go deep into the total quality control, with the whole activities somewhat suspended. How to correctly understand the present situation of the total quality control in China's industrial and communications enterprises, to discover the problems and to seek the measures to deal with the situation are becoming a pressing matter of the moment.

Methods To Study the Present Situation

1. Draw up the Investigation Form and Organize the Survey

Based upon the "Provisional Regulations on Total Quality Control by the Industrial Enterprises," issued in March 1980 by China, an investigation form

including 10 major respects with 204 items of content was drawn up regarding the quality management in implementing the total quality control's results, design, manufacture and the course of utilization, management by objective, the control of quality information, the quality policy, the education and training of quality management, the organization and its function of quality management, and mass activities of quality control, etc. Seven provinces and municipalities including Shanghai, Beijing, and Jiling and four industrial departments including mechanical and electronic and their quality control associations were organized to join the Group for Studying the Present Situation of Quality Management in carrying out the survey of 1,320 enterprises including the experimental units.

## 2. Use Computer To Establish the Data Base

According to the investigating data of 1,320 enterprises, the information data base of the present situation of quality control was established in using the microcomputer. The command file system was worked out with functions of statistics, inquiring, updating, adding or deleting, using the control program of DBASE II data base management system, thus making it possible to carry out statistics with the information of the data base in nine different forms including nationwide, or according to province or department and according to various categories.

## 3. Carry Out Analysis and Study Based on Statistics

### Results and Discussions

#### 1. Results (see Table 1)

Table 1-1. Statistics of Situations of Enterprises Winning Various Kinds of Awards

Items winning awards	National grade	Departmental grade	Provincial and city grade
Awards for quality control	0.7	3.5	6.2
Awards for quality products	20.7	40.1	54.6
Awards for outstanding quality control circles	10.4	27.2	41.0

Notes: Data in Table 1 to Table 6 are all percentage figure of the enterprises. Percentage figure of enterprises winning awards = number of enterprises winning awards/Total number of enterprises (i.e., 1,320).

A. Enterprises won quality control awards of national, provincial, city and departmental grades account for 10.4 percent. All these are enterprises doing a lot of work in carrying out the total quality control, having established relatively perfect quality assurance system improving the quality of products, cutting down the consumption, developing the varieties and yielding no table economic results, thus winning different grades of awards respectively, according to their various degrees.

Table 1-2. Statistics of Rate of Output Value of Enterprises' Quality Products

*Rate of output value of enterprises' quality products	Over 70 percent	Over 50 percent	Over 30 percent	Over 5 percent
Percentage of enterprises	5.98	10.75	26.21	28.40

\*The output value of quality products refers to the output value of quality products of grades including national, departmental, provincial, and city.

$$\text{The rate of output value of quality products} = \frac{\text{Output value of quality products}}{\text{Total output value of enterprises}}$$

B. About 50 percent of enterprises won the quality products awards of national, departmental, provincial, and city grades.

C. The rate of output value of quality products is low. Although enterprises won quality products awards of over provincial and city grades account for 50 percent, but enterprises with the rate of output value of quality products over 5 percent account for only 28.4 percent, this explains that about half of the quality products are not the major products of the enterprises concerned.

D. Enterprises won the title of outstanding quality control circle of national, departmental, provincial, or city grades account for about 40 percent of the total enterprises.

## 2. The Degree in Carrying Out the Total Quality Control

A. The present situation of quality control in the designing process of the enterprises. (See Table 2)

Enterprises using control method of quality management in the designing process account for about 50-60 percent, of which about 10-20 percent are doing well; enterprises which are able to use the technological method of quality management account for about 30-40 percent, of which less than 10 percent are doing well; the using of computers is just starting, accounts for only 0.8 percent. Incompleteness in the testing means for new products accounts for about 30.6 percent.

B. The present situation of quality control in enterprises' manufacturing process. (See Table 3)

(a) The traditional quality control giving priority to inspection is basically restored, about 90 percent of enterprises inspected can satisfy or can mostly satisfy the requirements. Although China issued in 1981 the national requirements for sample inspection, but about 47 percent of enterprises still have not adopted it.

(b) Viewing from the situation of measurement, technique outfit, equipment, and repairing, about 80 percent of the enterprises can satisfy or can mostly satisfy the requirements.

Table 2. Statistics of the Present Situation of Quality Control in the Designing Process of the Enterprises

	Items	Fully accomplished	Mostly accomplished	Unaccomplished
Control method	1. Work out procedure to develop new products	20.6	43.9	34.3
	2. Survey and forecast of market	14.3	63.7	20.9
	3. Technological forecast and feasibility study	9.6	53.9	35.1
	4. Design review	17.1	39.7	41.7
Technological method	5. Design of optimization	4.9	31.4	62.3
	6. Value engineering	2.4	27.0	69.2
	7. Mathematical statistical method	3.2	25.9	69.4
	8. Reliability engineering	8.0	44.2	46.4
	9. Application of computer	0.8	13.4	84.4
	10. Testing means for main function norms of new products	18.3	49.6	30.6

Table 3. Statistics of Present Situation of Quality Control in Enterprises' Manufacturing Process

Serial Nos	Items	Fully accomplished	Mostly accomplished	Unaccomplished
1	Inspection satisfies requirements of products' quality	33.3	57.9	7.9
2	Inspector adapts to requirements of products	26.0	64.3	8.7
3	Implement the selective inspection in percent	28.8	34.0	36.2
4	Implement sample inspection	20.9	30.3	47.9
5	Complete in technique outfit	25.3	62.7	11.7
6	Equipment precision satisfies quality requirements	15.6	69.6	14.0
7	Repair the equipment in time	19.7	67.0	12.4
8	Measuring work satisfies requirements of products' quality	27.2	59.5	12.4
9	Establish the necessary units of quality control	11.9	68.8	18.4
10	Launch the process statistics	11.4	57.8	29.9
11	Carry out process control (4MIE control)	4.1	52.5	42.5
12	Internal feedback of quality information	18.1	66.8	14.2
13	Use of computer	0.7	8.4	90.0

(c) Since the carrying out of the total quality control, the process control in putting prevention first has somewhat been strengthened, but there are still 30-40 percent of enterprises which did not do works in the respects of establishing units for quality control, of working procedures, of the process control, and of the internal feedback of information.

C. The present situation of management by objective. (See Table 4)

Table 4. Statistics of the Present Situation of Management by Objective

Serial Nos	Items	Fully accomplished	Mostly accomplished	Unaccomplished
1	Work out the policy of quality	24.3	55.2	19.6
2	Work out the quality objective	27.2	57.0	14.9
3	Develop quality objective level by level	17.0	50.7	30.5
4	Examine and diagnose quality objective	13.6	51.2	34.3
5	Good results through quality objective	9.6	52.1	37.5

About 20 percent of the enterprises have not launched the management by objective, enterprises which really result in improving the quality therewith account for about 10 percent, while about 40 percent of the enterprises having hardly any results.

D. The present situation of the control of quality information. (See Table 5)

Table 5. Statistics of the Present Situation of Control of Quality Information

Serial Nos	Items	Fully accomplished	Mostly accomplished	Unaccomplished
1	Work out the control method (system) of quality information	46.6	30.0	22.5
2	Establish various original records and report forms, data	76.2	19.6	3.4
3	Regularly arrange and analyze quality data	53.8	35.7	9.6
4	Analysis and feedback of quality information outside factory	51.3	37.6	10.3
5	Keep files of products' quality	55.1	25.6	18.5

Although the control system of quality information has begun to establish, still 22.5 percent of enterprises remained unsystematized. Various original quality records and report forms, data were paid attention to, and certain analysis was carried out, but the proportion of the enterprises which can integrate in the using of process statistics and process control and in carrying out control while discovering unusual situation is not big.



E. The present situation of the standardization of quality control.  
(See Table 6)

Table 6. Statistics of the Present Situation of the Standardization of Quality Control

Items	Fully accomplished	Mostly accomplished	Unaccomplished
Work out system of quality control standard	74.9		
Work out quality handbook of enterprises	4.2	9.9	84.7

From Table 6 it can be seen, although 74.9 percent of the enterprises have already worked out the system of quality control standard, enterprises which have published quality handbook completely according to the quality assurance system account for only 4.2 percent, those are just undergoing account for 9.9 percent, while 84.7 percent of the enterprises have done nothing about it.

F. The present situation of quality control education.

The development of basic education in total quality control is rather popular, but its depth is insufficient. Of the enterprises, 86.7 percent have planning for quality control education, 67.5 percent have their planning for quality control education channeling into the general planning of education for their staff and workers. Viewed from the range of education, the proportion of various levels to be educated is relatively high, e.g., enterprises which have their range of education for leading cadres to accept the total quality control education for above 8-16 hours reaching more than 50 percent account for 88 percent. But enterprises which have their range of education for technical personnel with an education over 48 hours reaching more than 50 percent account for only 60.9 percent. Viewed from the content of education, enterprises having popularized their education with the basic content of total quality control while deeply carried out education of mathematical statistics method and of other methods account for about 20 percent. (Statistical table is omitted here.)

G. The present situation of the quality management organizations and their functions.

At present, 47.8 percent of the enterprises have set up offices of total quality control, some enterprises still have full-time personnel for quality management in their quality management offices or other departments. Enterprises having more than five full-time personnel account for about 57.27 percent. Their main functions are to push on the total quality control, to assist the top management of the enterprises in working out the policy of quality, to carry out management by objective, to draw up plans for the upgrading of products to superiority and to go on with the examination and award of quality, etc. Yet the quality management organizations of about 30 percent of the enterprises have not been able to bring into play. (Statistical table is omitted.)

### 3. Discussions

A. In the 6 short years of implementing the total quality control, at least 10 percent of the enterprises have gained distinct economic results; only if it could be conscientiously persisted in the long run, more and more enterprises are certainly to be actually benefited therefrom, something also beneficial to the country and its people. Practice has proved: the guiding principle "Quality First" is effective, it should be seriously carried through all the way.

B. Quality consciousness in certain degree determines the depth and results in implementing the total quality control. Enterprises which are running well all possess a leading group with a very clear-cut quality consciousness. But there are 30 percent of enterprises of which the quality management organizations are only of undeserved reputation, this explains that the quality consciousness of the top management of these enterprises is not strong, they act merely according to orders from above and under pressure of the situation, of course the results can be foreseen. Therefore the education of quality consciousness must be enhanced.

C. The rate of quality products is on the low side, these quality products have not formed a certain productive capacity, this is a problem very anxiously to be solved. There are lots of factors bringing about such a situation, one of the important reasons is the enterprises gain nothing from the quality products. Statistical data reveal enterprises practicing quality products with superior prices account for only 14.2 percent. Therefore, works from two respects should be put on, one is the implementation of the policy of quality products with superior prices, it is up to the government to encourage the enterprises in expanding the output of quality products; on the other hand, the enterprises shall be educated to possess a strategy of long-term viewpoint, integrating the achievement of quality products with the improvement of the whole enterprise's quality so as to lay down the solid foundation for the existence and development of the enterprise, and finally the enterprise itself will be benefited.

D. Statistical quality control is the foundation of the total quality control. Due to historical causes, China enters into the total quality control directly from the quality control giving priority to inspection. Innumerable facts prove that the technical personnel masses of China's enterprises lack the necessary knowledge of mathematical statistics, while the foundation of the manufacturing workers in the respect of collecting the data and going through the necessary statistical analysis is weak. Thus in the course of designing, manufacturing, and inspection, the employment of means of statistics is not enough, lacking of strict quantitative analysis. Enterprises doing well in the process capability study and the process control account for only about 5 percent. The reason why the works of total quality control cannot develop more rapidly in depth is that, besides the aspect of consciousness and organization, the lack of necessary knowledge of mathematical statistics on the part of staff and workers is also one of the important causes. Only if the application of mathematical statistics in the quality control is paid attention to and the education of basic knowledge in mathematical statistics is strengthened, then

a solid foundation in the implementation of the total quality control can be laid down.

E. On the foundation of popularization, standards must be raised; and under the guidance of raising the standards, the popularization can then be done much better. Integrating with China's national conditions, many problems need to study in depth in pushing on the education of the total quality control, such as the quality assurance system, the management by objective, quality cost, mathematical statistics method, the application of computer in quality control, etc., all these are placed on the order of the day, necessitating the organization of forces and accelerating the pace of study.

F. Only by comparing can one distinguish, and only by distinguishing can one develop. The reason why the proportion of quality products up to the national grade which actually reach or surpass the international standard is not high, is also that our standard is not high. Some of the enterprises lack the necessary standards, although they want to join in the international market, but they know nothing about the international standards; their means of measuring and testing are insufficient, pending for renewal. If these problems are not properly solved, then the implementation of the total quality control is lack of necessary guarantee.

Original data adopted by this article are provided by comrades of associations of quality control in various provinces, municipalities and departments joining the Group in Studying the Present Situation of the Association of Quality Control of China, we extend to them our heartfelt thanks.

/9365

CSO: 4010/1014

NATIONAL DEVELOPMENTS

XIAMEN PROGRESS IN INFRASTRUCTURE CONSTRUCTION

OW111213 Beijing XINHUA in English 1042 GMT 11 Nov 85

/Text/ Xiamen, 11 Nov (XINHUA)--Major power and water supply schemes are being planned for Xiamen in Fujian province, which is one of China's four special economic zones.

A thermal power plant with a generating capacity of 600,000 kilowatts will be built on Xiamen island during the Seventh 5-Year Plan (1986-1990), according to local authorities.

Xiamen is now supplied by hydropower stations located in southern Fujian, which can barely meet demand during the dry seasons.

Also planned is a water-diversion project for Xiamen, now designated to practice special policies to attract foreign investment.

This will increase the supply of tapped water to Xiamen from 130,000 tons per day now to more than 300,000 tons in 1990.

During the Seventh 5-Year Plan period beginning 1986, the zone will continue focusing on building transport and telecommunications facilities as well.

Five deepwater berths will be built in the next 5 years to raise the port's annual cargo handling capacity from the present 2 million tons to over 10 million tons.

Another transport project to be built is a highway bridge to link the Xiamen Island with the mainland.

Installation of a 20,000-line program control telephone system, and expansion of the Xiamen International Airport will also be underway.

Local officials said more than 600 million yuan has been invested in infrastructure projects in the Xiamen special economic zone since 1980.

Projects already completed include the Huli Industrial Park, four berths able to accommodate up to 50,000-ton ships and Xiamen International Airport.

/12228

CSO: 4010/2003

NATIONAL DEVELOPMENTS

HUNAN LEADERS VISIT CHANGSHA INSTITUTES

HK120718 Changsha Hunan Provincial Service in Mandarin 2300 GMT 10 Nov 85

/Excerpt/ On 10 November, provincial party and government leaders including Mao Zhiyong, Xiong Qingquan, Wang Xiangqian, and (Sun Wensheng), as well as leading comrades of the Provincial Committee for Science and Technology, visited the Mining Institute, the Institute for Chinese Herbal Medicine, and the Mining Industry Institute in Changsha.

After listening to the reports of the institutes, the leaders commended them for their achievements made following the structural reforms. The leaders encouraged them to make greater efforts toward invigorating Hunan.

On the morning of 10 November, the provincial leaders first visited the Changsha Mining Institute. After listening to the report delivered by the institute leader, Comrade Mao Zhiyong said: We have come here to learn about your experiences and to solicit opinions from you. Your main focus of study is on underground mining. Judging from the province's situation, many of the province's mines are on a small scale and face many problems. Under the prerequisite of studying large-scale mining, it would be better if you could also study that on a small scale. Once you have done this, you can make great contributions to the province. The problems you have mentioned will be studied and handled by us and the Changsha authorities.

Comrade Mao Zhiyong and other leading comrades then went to the Institute for Chinese Herbal Medicine. After listening to the report delivered by the institute leader, they expressed their views on its development. Mao Zhiyong said: The province is rich in Chinese herbal medicine resources. It is hoped that you will cooperate with relevant factories on a profitsharing basis. The institute should work out plans, while the factories should take care of the rest, so as to develop the pharmaceutical and tonic food industries. The comrades of the institute agreed with this plan.

In the afternoon, Mao Zhiyong and other leaders also visited the Changsha Ministry Industry Institute.

/12228  
CSO: 4008/2024

NATIONAL DEVELOPMENTS

BRIEFS

INTERNATIONAL COMPUTER EXHIBITIONS--Beijing, 4 Oct (XINHUA)--A 6-day international exhibition and symposium on computer graphics technology and application opened here today. Nineteen leading international computer companies from Federal Germany, France, the United States and Hong Kong, including Siemens AG, Comef Instruments S.A., Computervision Designer systems and the Control Data Corporation, are displaying sophisticated hardware and software at the Beijing exhibition center. The 500 exhibits include computer drafting equipment, laser printers, software systems used in designing, planning and management, and color graphic terminals. An official of the Beijing sub-committee of the China Council for the Promotion of International Trade, which is organizing the exhibition, said this was the first such specialized display to be held in China. The exhibition ends on Wednesday. Meanwhile, an international symposium on computer graphics technology is being held simultaneously at the Beijing Institute of Technology. [Text] [Beijing XINHUA in English 1556 GMT 4 Oct 85] /9604

SYMPOSIUM EXAMINES MICROCOMPUTER USE--Hefei, 20 Oct (XINHUA)--A national symposium here today showed that micro-computers have been increasingly widely applied to instruments and meters in China. Experts from 28 provinces, municipalities and autonomous regions met to exchange the results achieved in using micro-computers to upgrade instruments and meters in electric power, coal, petroleum, chemical, metallurgical, machine building, electronics, transport, textile and light industries. More than 200 papers were presented to the meeting. A 7-day exhibition on the similar subject also opened here today. [Text] [Beijing XINHUA in English 1631 GMT 20 Oct 85] /9604

MAJOR INTEGRATED CIRCUIT APPROVED--Beijing, 24 Oct (XINHUA)--China's first major integrated circuit, a 16-part static random access memory (SRAM), was given official approval at an appraisal meeting here on Wednesday. It was produced by the Research Institute of Microelectronics attached to Qinghua University earlier this year. The circuit, on a silicon chip measuring only 28 square millimeters and 0.003 mm thick, contains more than 108,000 transistors and other devices. SRAMs are key parts in micro-computers and automatically-controlled equipment. The 16-part SRAM greatly enhances a computer's capacity to store information,

said Li Zhijian, Director of the Institute. The circuit has been working very well during reliability trials over the past few months, he added. The Institute plans to publish the techniques used to make the circuit. [Text] [Beijing XINHUA in English 1526 GMT 24 Oct 85] /9604

MICROCOMPUTER PRODUCTION LINE BEGINS--Fuzhou, 4 Nov (XINHUA)--An imported micro-computer production line, with an annual capacity of 10,000 units, went into trial operation in this capital of Fujian Province today. The line, the first in Fujian, uses equipment and technology from Japan, the United States and Hong Kong, according to Lin Riyu, general manager of the provincial computer company. Fujian now has 15 computer factories employing 4,300 people. [Text] [Beijing XINHUA in English 1451 GMT 4 Nov 85] /9604

ROBOT DEVELOPMENT--Nanjing, 9 Nov (XINHUA)--China has over 100 industrial robots and 1,000 mechanical hands for assembling, casting, forging, electroplating, and whitewashing. More than 400 specialists and college professors are engaged in the study and development of robots, which began in China in the 1970s. This was reported at an academic conference on robots here last week. More than 130 experts and scholars from all over the country attended the conference which received 70 papers. China is still at the experimental stage, the conference was told, and more efforts will be devoted to robot development in the coming years. China has imported a number of robots for teaching and industrial use over the past few years, and conducted a series of academic exchanges. "We are developing an intelligent robot, which will have visual sense and recognize an object's shape, size, color and distance," said Shen Nanxian at the conference. Shen, associate professor of the Chengdu Telecommunication Engineering Institute in Sichuan Province, said that he and his colleagues planned to develop the robot in a year. His first robot, which he described as an elementary one, was placed at the entrance of an exhibition hall in Urumqi, capital of the Xinjiang Uygur Autonomous Region. It is dressed as a Uygur girl which can say "hello" and deliver pamphlets and materials to visitors, as well as pointing out the way in for them. [Text] [Beijing XINHUA in English 0808 GMT 9 Nov 85] /9604

CHINA, JAPAN COOPERATION--On 20 September, China and Japan signed an agreement on implementation of technical cooperation in overall agricultural experimentation projects for the Sanjiang Plain in Harbin. Li Zhentao, vice chairman of the provincial Science and Technology Commission, and Jiye Yafu, leader of the implementation agreement delegation of Japan's international advisory group, signed the agreement on behalf of their own countries. According to this agreement, China and Japan will cooperate in experiments for the development of the Sanjiang Plain of our country. In 5 years, Japan will give free equipment aid worth more than 10 million yuan in Renminbi to our country and will send experts and receive our personnel who are to become engaged in advanced studies. Hou Jie, governor, and Wang Lianzheng, vice governor, of Heilongjiang Province, as well as relevant responsible persons of the State Science and Technology Commission, the Ministry of Water Resources and Electric Power, and the Ministry of Agriculture, Animal Husbandry, and Fishery attended the agreement-signing ceremony. /Text/ /Harbin Heilongjiang Provincial Service in Mandarin 2200 GMT 20 Sep 85 SK/ 12228



HUNAN GOVERNOR ATTENDS MEETING--The provincial meeting on science and technology work opened at Changsha's (Dongling) guesthouse today. Provincial Party and government leaders Xiong Qingquan, Wang Xiangtian, Kong Anmin, Chen Yufa, and Chen Hongxi attended the meeting. Some 530 people attended the meeting, including party and government leaders in charge of science and technology work, and directors of scientific and technological commissions from all prefectures, autonomous prefectures, and cities; responsible persons of planning and economic commissions of cities directly under the provincial authorities; standing committee members of the provincial scientific and technological specialists and advisors committee; members of the provincial leading group for science and technology; leaders of the relevant provincial departments, bureaus, commissions, and offices; and responsible persons of universities and colleges, provincial organs, and central scientific research institutes in Hunan. The meeting will last 5 days. The participants studied relevant documents of the meeting this morning and held a meeting in the afternoon. The meeting was presided over by Wang Xiangtian, Standing Committee member of the Provincial CPC Committee and provincial vice governor. (He Xiangchu), director of the provincial Science and Technology Commission, gave explanations to the suggestions put forward by the Provincial CPC Committee and government on implementing the decision of the CPC Central Committee on reforming the scientific and technological structure. Comrade Wang Xiangtian spoke at the meeting. /Excerpts/ /Changsha Hunan Provincial Service in Mandarin 1100 GMT 11 Nov 85 HK/ 12228

SCIENTIFIC, TECHNOLOGICAL STRUCTURE REFORM--At the provincial science and technology meeting opened yesterday /11 November/, (He Xiangchu), director of the provincial Science and Technology Commission, put forward the main tasks in the reform of the provincial scientific and technological structure. He said that efforts should be made to build a new scientific and technological system within 5 years which: Closely combines science, technology and production; has a rational setup; is active and flexible in its operation; and produces new achievements in scientific research. To fulfill this task, he put forward six suggestions on reform: /passage indistinct/ In conclusion (He Xiangchu) stressed that it is necessary to create an environment for scientific and technological personnel under which they can be entirely free from worries, and engage in creative work attentively. In addition, it is necessary to vigorously command outstanding scientific and technological personnel who: Work hard; have the courage to tackle difficult problems; are not concerned with their own promotion, fame, or benefit; and who have great ideals and dedicated spirit. Scientific and technological personnel must pay serious attention to the four modernizations and the future of the motherland, and work hard to serve economic construction. /Text/ /Changsha Hunan Provincial Service in Mandarin 2300 GMT 11 Nov 85 HK/ 12228

PRC, POLAND S&T AGREEMENT--Warsaw, 12 Oct (XINHUA)--A Sino-Polish agreement on scientific and technological cooperation for 1986 was signed here today. The agreement involves 63 projects covering various fields such as machine building, chemical industry, light industry and electronics. The agreement was reached at the just-concluded 18th conference of the Chinese-Polish union committee for economic, trade and scientific-technical cooperation. /Text/ /Beijing XINHUA in English 0714 GMT 13 Oct 85 OW/ 12228



FORUM ON HEAT TRANSFER RESEARCH--Beijing, 15 Oct (XINHUA)--More than 150 scientists from Asia, North America, Europe and Oceania met here today at an academic forum to share their findings in heat transfer research. Sponsored by Qinghua University, the 4-day forum will hear 110 papers read by scholars from Australia, Britain, Canada, Federal Germany, Italy, Japan, the United States and China. Heat transfer is relevant to the construction, machinery, electrical instrument and chemical industries, and also has close links with the development of space technology, nuclear energy and microelectronics. Over the past several years, Chinese scientists have made remarkable progress in the research of radiative and industrial heat transfer, heat conduction, natural convection, utilization of heat exchangers, heat and mass transfer and two-phase flow, according to sources at the symposium. /Text/ /Beijing XINHUA in English 1531 GMT 15 Oct 85 OW/ 12228

CSO: 4010/2003

PHYSICAL SCIENCES

IMPROVED METHOD FOR TRANSONIC FLOW CALCULATION PROPOSED

Beijing SHUZHJ JISUAN YU JISUANJI YINGYONG [JOURNAL OF NUMERICAL METHODS AND COMPUTER APPLICATIONS] in Chinese Vol 6 No 1, (Paper received 9 Apr 83) Mar 85 pp 57-64

[Article by Luo Shifeng [5012 0013 7685], Computing Center, Chinese Academy of Sciences; "A Variable-Parameter Type-Dependent Splitting Scheme"]

[Text] The steady-state transonic flow field consists of the subsonic and supersonic regions. In the subsonic region, AF1 scheme is used, and in the supersonic region, AF2 scheme is used. The parameter in AF1 scheme is linearly variant with period. We have calculated a lot of cases. Results indicate that the convergence rate of the type-dependent splitting scheme is very fast.

I. Introduction

The transonic constant small-disturbance computation method was first proposed by Murman and Cole in 1971. They used the line relaxation iterative method, which has subsequently found wide use. Experience has shown that the line relaxation iterative method converges very slowly, and the finer the grid, the slower the convergence. In order to obtain reliable results, with less than 3000 grid points the line relaxation iterative method may require close to 1000 iterations or even as many as 2000 or more [2]. This has made it urgently necessary to find a computation method that converges more rapidly.

Ballhaus et al. in [3] propose two approximate factor solution methods, which they call AF1 and AF2. They feel that their AF1 method converges the fastest, while the AF2 method is also much faster than the line relaxation iterative method. For transonic flow calculations, the authors in Ref [3] propose a method of this type; they use the AF1 method in the subsonic region, while in the supersonic region they use an offset difference grid for  $\phi_{xx}$ . The problem of "moving shock wave instability" has been encountered in real calculations, and in order to overcome this difficulty, a stable factor must be added in the initial period of the calculation; it is eliminated after a few iterations. This is extremely cumbersome, and therefore the method is not used in transonic flow calculations. The AF2 method is usually used instead.

In the present we use the approximation analysis method, with different time-dependent equations in the subsonic and supersonic regions. In the time-

dependent equation for the subsonic region, our approximation analysis yields the AF1 method. In the time-dependent equation for the supersonic region, the analysis yields the AF2 method. In the computation process we combine the AF1 and AF2 methods, taking account of the rapid convergence of AF1 in the elliptical equation; although in the supersonic region the AF1 method is inapplicable, however, the AF2 method is fairly effective and easy to use. This overcomes the problem of moving-shock wave instability. This combination takes advantage of the best features of each method and gives a rational computation procedure, we call it the type-dependent splitting method.

## II. Choice of a Small-Disturbance Equation and Its Time-Dependent Equations

The chosen small-perturbation velocity potential equation in Cartesian coordinates  $x, y$  is:

$$\begin{aligned} -A\phi_{xx} + \phi_{yy} &= 0, \\ A &= -(1 - M_\infty^2) + (\gamma + 1)M_\infty^2\phi_{xx}, \end{aligned} \quad (2.1)$$

when  $\phi$  is the small-disturbance velocity potential function,  $M_\infty$  is the incident flow Mach number, and  $\gamma$  is the specific-heat ratio. When  $A < 0$ , equation (2.1) is an elliptical partial differential equation; when  $A > 0$ , it is a hyperbolic partial differential equation.

A grid is superimposed on the computation area and  $\phi(x_i, y_j)$  is used to denote the functional value of  $\phi$  at grid point  $(x_i, y_j)$ ; and  $x_i = i\Delta x$ , and  $y_j = j\Delta y$ ,  $\Delta x, \Delta y$  are the increments. In the iteration process, each iteration is regarded as a different time level, and accordingly the virtual time  $t$  is introduced.  $\phi(x_i, y_j, t_n)$  is used to denote the functional value of  $(x_i, y_j)$  at grid point  $(x_i, y_j)$  in the  $n$ th-order iteration, where  $t_n = n\Delta t$  and  $\Delta t$  is the virtual time increment; the above is abbreviated as  $\phi_{ij}^n$ .

Performing the difference calculation on  $\phi_{xx}$ , we obtain a partially implicit, partially explicit difference grid.

$$(\phi_{xx})_{i,j}^n = \frac{1}{\Delta x^2} [\phi_{i-1,j}^{n+1} - (1 + a\Delta x)\phi_{i,j}^{n+1} - (1 - a\Delta x)\phi_{i+1,j}^n + \phi_{i+1,j}^n], \quad (2.2)$$

where  $a > 0$

The right side of equation (2.2) is expanded in a Taylor series, in which only the terms in  $\Delta t, \Delta x, \Delta t\Delta x, \Delta x^2$  and  $\Delta x^2$  are retained, the others are discarded. Similarly,  $\phi_{yy}$  is expanded. Substituting the results into equation (2.1), a time-dependent equation is obtained as

$$-A\phi_{xx} + \phi_{yy} - 2p\phi_{xt} - 2q\phi_{yt} - R\phi_t = 0, \quad (2.3)$$

where

$$p = -\frac{1}{2}A\frac{\Delta t}{\Delta x}, \quad q = \frac{1}{2}\frac{\Delta t}{\Delta y}, \quad R = a\left(-A\frac{\Delta t}{\Delta x} + \frac{\Delta t}{\Delta y}\right).$$

In equation (2.1), when  $A < 0$ , the difference method of equation (2.2) is used to obtain a solution. This is approximately equal to solving the time-dependent equation (2.3). We use this method to obtain a time-dependent equation. Under fixed-constant boundary conditions, as  $t \rightarrow \infty$ , if equation (2.3) has a solution it is the solution of fixed-constant equation (2.1). We therefore analyze the characteristics of equation (2.3) [8]. Suppose that the equation has been linearized in a local domain and let  $p$ ,  $q$  and  $R$  be any constants. Taking the highest-order term, we obtain

$$-A\phi_{xx} + \phi_{yy} - 2p\phi_{xt} - 2q\phi_{yt} = 0. \quad (2.4)$$

Making the transformation

$$\begin{cases} T = t - \frac{px}{A} + qy, \\ x = x, \\ y = y, \end{cases} \quad (2.5)$$

equation (2.4) in the new system of coordinates is

$$-A\phi_{xx} + \phi_{yy} + \left(\frac{p^2}{A} - q^2\right)\phi_{TT} = 0. \quad (2.6)$$

When  $A > 0$ , and when the condition

$$p^2 > Aq^2 \quad (2.7)$$

is met, equation (2.6) is also a hyperbolic partial differential equation and the  $x$  direction is still the direction of advance.

The characteristic cone equation for equation (2.4) is

$$(qx - py)^2 + At^2 - 2ptx + 2qAty = 0. \quad (2.8)$$

When condition (2.7) is met, it is a centered curved surface. For  $A > 0$ ,  $p > 0$ , it has the characteristic cone shown in Figure a, while for  $A < 0$ ,  $p > 0$  its characteristic cone is as shown in Figure b.

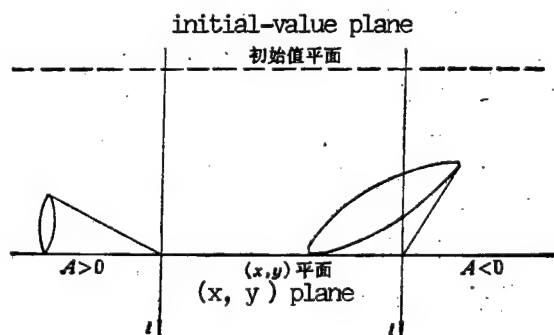


Figure a. Figure b.

It can be seen from these curves that: (k) When  $A > 0$ , the characteristic cone includes the  $t$  axis, so that it is dependent on the value specified by the initial plane. Because we did not expect the initial value to have an effect, we had to increase the resistance term  $\phi_t$  to prevent its producing any effect. (ii) When  $A > 0$ , the coefficient  $p$  of  $\phi_{xt}$  defines the location of a centered curve in any  $x$  cross section. If  $p$  is positive, the characteristic cone is located in the lower half of the  $xy$  plane as shown in Figure a. This guarantees that the subsequent results are dependent on the earlier values in a correct way. If  $p < 0$ , then the characteristic cone is rotated toward the other side, destroying this correct relationship; thus  $p$  must always be chosen positive and we do not need the  $\phi_t$  term.

Based on this analysis, the  $\phi_t$  term must be kept in the subsonic region. Accordingly, in equation (2.3) we choose  $p = q = 0$ ,  $R = 1$ , obtaining the time-dependent equation

$$\phi_t + A\phi_{xx} - \phi_{yy} = 0. \quad (2.9)$$

In supersonic region we can choose  $p = 1/2$ ,  $q = 0$ ,  $R = 0$ . This choice agrees with condition (2.7), and accordingly we obtain the time-dependent equation

$$\phi_{xt} = -A\phi_{xx} + \phi_{yy}. \quad (2.10)$$

Equations (2.9) and (2.10) are the time-dependent equations which we should select.

### III. Time-Dependent Splitting

After a grid is superimposed on the computation area, we call the grid points where  $A > 0$  the supersonic points and the other points, at which  $A < 0$ , the subsonic points. The formulas used for solution are second-order partial differential equations; when we perform the difference calculation, they are dependent on the surrounding 5 grid points, which we call 5-point difference grid. If in the 5-point difference grid formula each point is subsonic, the region constructed from these points is called a subsonic region. If one of the five grid points is supersonic, then the area formed by these points is called "non-subsonic."

We use the symbol  $\delta_x^{(-)}$  to denote the first-order backward difference operator,  $\delta_x^{(t)}$  to denote the first-order forward difference operator, and  $\delta_{xx}$  to denote a second-order central difference operator. We use similar symbols for  $y$ .

We make a difference computation on the time-dependent equation (2.9) for the subsonic region. We use an implicit-difference grid, omitting the subscripts for convenience:

$$\frac{\phi^{s+1} - \phi^s}{\tau} + A\delta_{xx}\phi^{s+1} - \delta_{yy}\phi^{s+1} = 0,$$

where  $\tau$  is the time increment.

This implicit difference grid is inconvenient for computation, and we therefore perform approximate splitting on it. First, we rewrite the above equation as

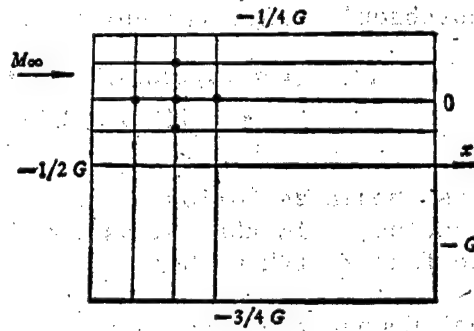
$$(E + \tau A \delta_{xx} - \tau \delta_{yy})(\phi^{n+1} - \phi^n) = \tau(-A \delta_{xx} + \delta_{yy})\phi^n,$$

where  $E$  is the identity operator. The above formula can be approximately split as follows.

$$(E + \tau A \delta_{xx})(E - \tau \delta_{yy})(\phi^{n+1} - \phi^n) = \tau(-A \delta_{xx} + \delta_{yy})\phi^n. \quad (3.1)$$

which differs from the above equation by  $O(\tau^2)$ .

Figure c.



Similarly, for time-dependent equation (2.10) in the supersonic region we use the implicit-difference grid

$$\delta_x^{(-)}(\phi^{n+1} - \phi^n) + \tau A \delta_x^{(-)} \delta_x^{(-)} \phi^{n+1} - \tau \delta_{yy} \phi^{n+1} = 0.$$

Using the method described above, we perform approximate splitting into

$$(E + \tau A \delta_x^{(-)})(\delta_x^{(-)} - \tau \delta_{yy})(\phi^{n+1} - \phi^n) = \tau(-A \delta_x^{(-)} \delta_x^{(-)} + \delta_{yy})\phi^n. \quad (3.2)$$

Equations (3.1) and (3.2) and original equations (2.9) and (2.10) have a difference of  $O(\tau)$ . In Ref [3], equation (3.1) is called AF1 method and equation (3.2) is called AF2 method.

In the transition from the subsonic region to the supersonic region, when  $A_{i-1,j} < 0$ ,  $A_{ij} > 0$ , we call point  $(x_i, y_j)$  the parabola point. At the parabola point, let  $A = 0$  [4]. Then the time-dependent equation is

$$\phi_{xx} - \phi_{yy} = 0. \quad (3.3)$$

and its difference equation is

$$(\delta_x^{(-)} - \tau \delta_{yy})(\phi^{n+1} - \phi^n) = \tau \delta_{yy} \phi^n. \quad (3.4)$$

During transition from the supersonic to the subsonic region, for  $A_{i-1,j} > 0$ ,  $A_{i,j} < 0$ , we call point  $(x_i, y_j)$  the shock wave point. At these points we choose the following time-independent equation [4] (for simplification we omit the subscript  $j$  in  $A_{i,j}$ ):

$$\phi_{xx} + A_{i-1} \phi_{xx} + A_i \phi_{xx} - \phi_{yy} = 0. \quad (3.5)$$

When  $A > 0$ , we use an eccentric difference grid for  $\phi_{xx}$ , while when  $A < 0$  we use a centered difference grid for it. Its approximate splitting formula is

$$\begin{aligned} & [E + \tau A_i \delta_x^{(+)} + \tau A_{i-1} \delta_x^{(-)}][\delta_x^{(-)} - \tau \delta_{yy}](\phi^{n+1} - \phi^n) \\ & = \tau[(-A_{i-1} \delta_x^{(-)} - A_i \delta_x^{(+)})\delta_x^{(-)} + \delta_{yy}]\phi^n. \end{aligned} \quad (3.6)$$

If we let  $\alpha = \frac{1}{\tau}$ , then equations (3.1), (3.2), (3.4) and (3.6) can be written in terms of parameter  $\alpha$ . In the subsonic range the splitting formula is

$$(\alpha + A\delta_{xx})(\alpha - \delta_{yy})(\phi^{n+1} - \phi^n) = \omega\alpha[-A\delta_{xx} + \delta_{yy}]\phi^n. \quad (3.7)$$

In the nonsubsonic range its splitting formula is

$$\begin{aligned} & [\alpha + (1 - \epsilon_{i-1})A_{i-1}\delta_x^{(-)} + \epsilon_i A_i \delta_x^{(+)}][\alpha\delta_x^{(-)} - \delta_{yy}](\phi^{n+1} - \phi^n) \\ & = \omega\alpha[(-\epsilon_i A_i \delta_x^{(+)} - (1 - \epsilon_{i-1})A_{i-1}\delta_x^{(-)})\delta_x^{(-)} + \delta_{yy}]\phi^n, \end{aligned} \quad (3.8)$$

where  $\beta_i$  is chosen as follows: if  $A_i > 0$  then  $\beta_i = 0$ ; if  $A_i < 0$ , then  $\beta_i = 1$ . In the equation,  $\omega$  is the relaxation factor. It is also possible to omit the relaxation factor, taking  $\omega = 1$ .

#### IV. Actual Computations and Analysis of Results

In the computations, we begin by calculating the value of  $A$  for the grid and distinguish the subsonic and nonsubsonic regions. In the subsonic region we use equation (3.7), carrying out the specific computation in two steps:

$$\text{i} \quad (\alpha + A\delta_{xx})f = \omega\alpha[-A\delta_{xx} + \delta_{yy}]\phi^n. \quad (4.1)$$

$$\text{ii} \quad (\alpha - \delta_{yy})c = f. \quad (4.2)$$

after which we calculate  $\phi^{n+1} = \phi^n + c$ .

In the nonsubsonic region, we use equation (3.8), also performing the computation in two steps:

$$\begin{aligned} \text{i} \quad & [\alpha + (1 - \epsilon_{i-1})A_{i-1}\delta_x^{(-)} + \epsilon_i A_i \delta_x^{(+)}]f \\ & = \omega\alpha[(-\epsilon_i A_i \delta_x^{(+)} - (1 - \epsilon_{i-1})A_{i-1}\delta_x^{(-)})\delta_x^{(-)} + \delta_{yy}]\phi^n. \end{aligned} \quad (4.3)$$

$$\text{ii} \quad (\alpha\delta_x^{(-)} - \delta_{yy})c = f. \quad (4.4)$$

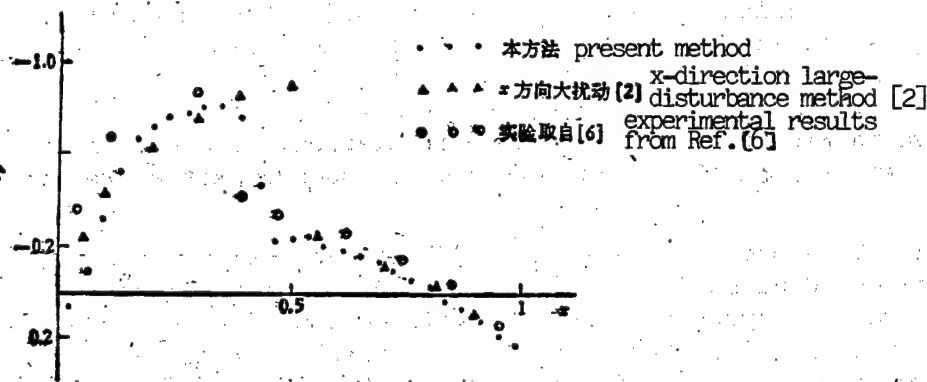


Figure 1 NACA0012,  $M_\infty = 0.8$ ,  $\alpha_A = 0^\circ$

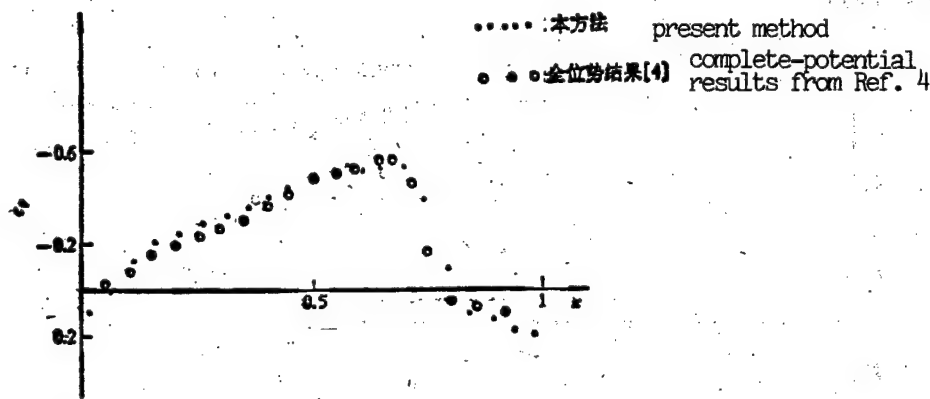


Figure 2 NACA64A006  $M_\infty = 0.92$ ,  $\alpha_A = 0^\circ$

after which we find  $\phi^{n+1} = \phi^n + c$ .

There are two methods of choosing  $\alpha$  in the calculation. One is to choose a fixed content in both the subsonic and nonsubsonic regions, which is called the fixed parameter type-dependent splitting method. The other method is to choose a fixed constant  $\alpha$  in the nonsubsonic region and to let the value of  $\alpha$  vary in the subsonic region. With a cycle of  $M$  iterations, within a cycle the value of  $\alpha$  is chosen to vary linearly. Let  $\alpha_1$  express the value of  $\alpha$  in the subsonic region, and let  $\alpha_2$  express its value  $\xi$  in the nonsubsonic region. We use the following formula to calculate the value of  $\alpha$  in the subsonic region.

$$\begin{cases} \alpha_1^{(1)} = c_1, \\ \alpha_1^{(k)} = \alpha_1^{(k-1)} + c_2(M+1-k), \\ k = 2, 3, \dots, M. \end{cases} \quad (4.5)$$

In the non subsonic region,  $\alpha_2 = C_3$ . Above,  $c_1$ ,  $c_2$  and  $c_3$  are constants



We performed the calculation for the NACA 64A006 wing shape with  $M_\infty = 0.92$  and  $\alpha_A = 0^\circ$  ( $\alpha_A$  is the incident-flow angle of attack). The grid consisted of  $157 \times 26$  points and the calculation area was a square measuring  $6 \times 6$  times the wing chord. In all the calculation examples the far-field boundary conditions are these shown in Figure c, and  $G$  is the circulation. The convergence criterion in  $\max_{i,j} |\phi_{i,j}^{n+1} - \phi_{i,j}^n| < 5 \times 10^{-3}$ . This criterion is used except where otherwise stated.

We use the AF2 method [4], performing 376 iterations. We used the fixed-constant type-dependent splitting method, making 306 iterations. We then used the variable-parameter type-dependent splitting method with  $c_1 = 30$ ,  $c_2 = 1.08$  and  $c_3 = 20$ , performing 176 iterations. The variable-parameter type-dependent splitting method was thus twice as good as the AF2 method. The pressure coefficients, shown in Figure 2, are close to the full potential results, results given in Ref [5].

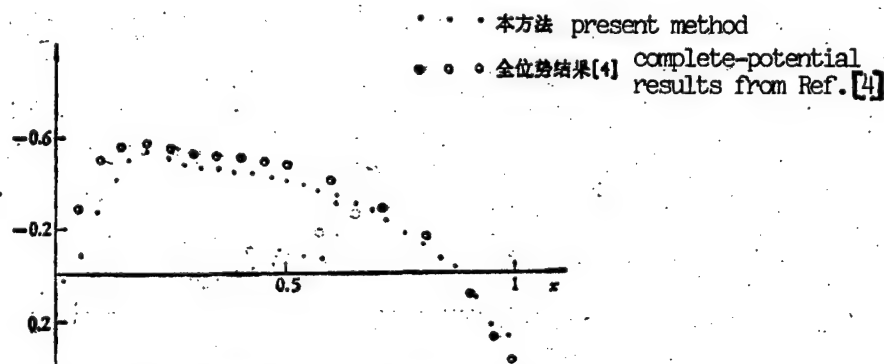


Figure 3 NLR0.11-0.75-0.9,  $M_\infty = 0.7861$ ,  $\alpha_A = 0^\circ$

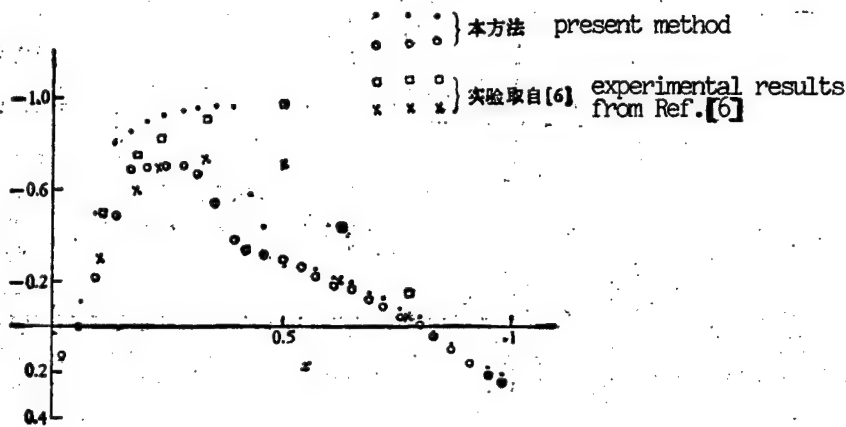


Figure 4 NACA0012  $M_\infty = 0.8$ ,  $\alpha_A = 1^\circ$

Calculation for NACA 0012 wing shape,  $M_\infty = 0.8$ ,  $\alpha_A = 0^\circ$ . Grid,  $157 \times 26$  points,  $c_1 = 30$ ,  $c_2 = 108$ ,  $c_3 = 10$ . Computation area as above, 128 iterations. The pressure coefficients are given in Figure 1. It is evident from Figure 1 that the results are similar to those for large perturbations in the  $x$  direction given in Ref [2]; except for a slight discrepancy in the shock wave position they coincide with the experimental results reported in Ref [6].

Figure 3 shows the pressure coefficients for the NLR 0.11-0.75-0.9 wing shape with  $M_\infty = 0.7861$  and  $\alpha_A = 0^\circ$ . The grid used was  $157 \times 26$  points,  $c_1 = 30$ ,  $c_2 = 1.08$ ,  $c_3 = 20$ . The calculation area was as above; 104 iterations were used. The figure also shows the full-potential results [5]; the two sets of results are in general agreement.

Figure 4 shows the pressure coefficients for the NACA 0012 wing shape with  $M = 0.8$ ,  $\alpha_A = 1^\circ$ ,  $c_1 = 20$ ,  $c_2 = 2$ ,  $c_3 = 30$ . The grid was  $157 \times 52 = 8164$  points. The calculation area was a rectangle measuring  $6 \times 12$  chord lengths; 234 iterations were used. The figure also shows experimental results from Ref [6].

Figure 5 shows results for the NACA 0012 wing section with  $M_\infty = 0.9$ ,  $\alpha_A = 0^\circ$  and with  $M_\infty = 0.96$  and  $\alpha_A = 0^\circ$ ,  $c_1 = 20$ ,  $c_2 = 10$ ,  $c_3 = 30$ , using  $121 \times 60 = 7260$  grid points. The calculation area was a rectangle measuring  $6 \times 20$  wing chord lengths. We used 180 iterations for  $M_\infty = 0.9$  and  $\alpha_A = 0^\circ$  and 205 iterations for  $M_\infty = 0.95$  and  $\alpha_A = 0^\circ$ ; the criterion used was  $\max |\phi_{i,j}^{n+1} - \phi_{i,j}^n| < 10^{-4}$ . Table 5 shows Rizzi's results [7] for  $M_\infty = 0.95$  and  $\alpha_A = 0^\circ$ . The two are in fairly good agreement.

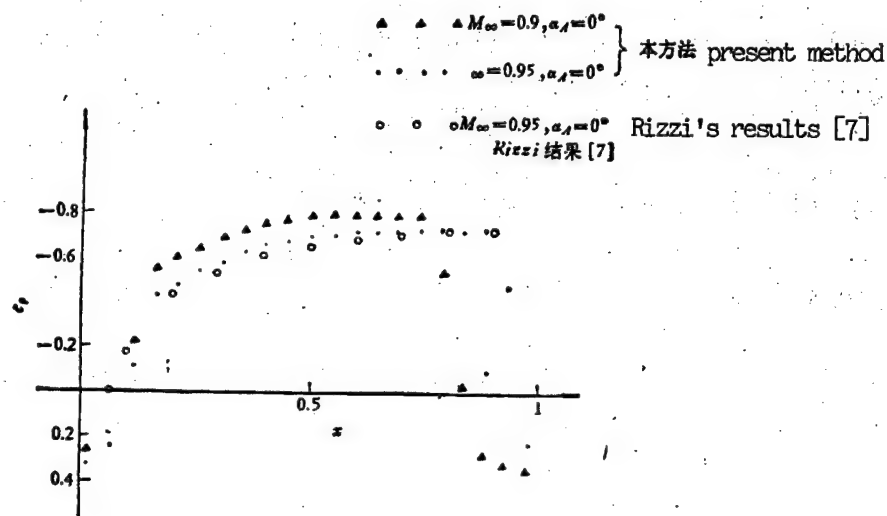


Figure 5. NACA0012  $M_\infty = 0.9$ ,  $\alpha_A = 0^\circ$ ,  $M_\infty = 0.95$ ,  $\alpha = 0^\circ$

To summarize, it is evident that the variable-parameter type-dependent splitting method is faster than the AF2 method; the calculation results indicate that it is twice as fast. In addition, when the number of grid points is increased, the convergence is still very rapid; with more than 1000 grid points it still requires only about 200 iterations. In a comparable example, Ref [2] reports that with more than 1000 grid points the line overrelaxation method required more than 1000 iterations. Calculations can also be made for the NACA 0012 wing with  $M_\infty = 0.95$ . It is pointed out in Ref [2] that the linear relaxation method has certain difficulties, so that the variable-parameter type-dependent splitting method is a fast and reliable computation method.

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PHYSICAL SCIENCES

GEOMETRIC DEFINITION OF UNIFORM B-SPLINE CURVES

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[Text] Abstract: J.H. Clark defined uniform B-spline curves and the standard uniform B-spline. He has not however, established the general forms. Based on Clark's work, we establish the general geometric definition of uniform B-spline curves, derive the general formulas of uniform B-spline basic functions, and obtain a series of properties and formulas calculating the uniform B-spline basic function and uniform B-spline curves.

I. Geometric Definition

B-splines were first proposed by I.J. Schoenberg. Subsequently, D. de Boor and M.G. Cox independently obtained recursion formulas for them. W.J. Gordon, R.F. Riesenfeld and A.R. Forrest expanded the Bezier method and applied B-splines to CAGD [Computer-Assisted Graphic Design]. There are a variety of definitions of B-splines, including a difference product definition, but is it possible, as in the case of the Bezier curves [2,3], to derive the basic formula for B-splines from the basic geometric requirements applying to the curves, thus establishing a geometric definition for uniform B-spline curves? Clark has done so [1]: an m-th order uniform B-spline curve can be expressed by the equation

$$P_i(t) = \sum_{j=0}^m f_{m,j}(t) \cdot V_{i+j}, \quad 0 \leq t \leq 1, \quad i = 1, 2, \dots, n. \quad (1)$$

While maintaining the external features of the Bernstein formula for the Bezier curve, this approach changes it into a segmented spline curve. By successively connecting the vertices  $\{V_i\}_{i=1}^{n+m}$ , we obtain a broken line which is a B-characteristic polygon;  $f_{m,j}(t)$  is the basic formula for m-th order uniform B-spline. The spline curve thus expressed in terms of equation (1) has two distinctive characteristics.

(i) Local approximation. The s-th spline segment has is related to maximum of  $m + 1$  vertices  $\{V_i\}_{i=s}^{s+m}$  and is unrelated to other vertices.

(ii) All spline segments use a uniform basic formula  $\{f_{m,i}(t)\}$ , independent of the vertices. The basic formula is a polynomial of maximum order  $m$  in parameter  $t$ :

$$f_{m,i}(t) = \sum_{j=0}^m a_{i,j} t^j, \quad 0 \leq t \leq 1, \quad i = 0, 1, \dots, m \quad (2)$$

or can be written in matrix form as follows:

$$[f_{m,0}(t) f_{m,1}(t) \dots f_{m,m}(t)] = [1 \ t \dots t^m] \begin{bmatrix} a_{0,0} & a_{0,1} & \dots & a_{0,m} \\ a_{1,0} & a_{1,1} & \dots & a_{1,m} \\ \vdots & \vdots & & \vdots \\ a_{m,0} & a_{m,1} & \dots & a_{m,m} \end{bmatrix}.$$

This has a total of  $(m + 1)^2$  unknown coefficients, namely the matrix elements  $a_{ij}$ ,  $i, j = 0, 1, \dots, m$ .

In order to determine uniquely the completely unknown coefficients, we must supply the necessary constraints on the spline curve, i.e. we must define iii and iv as two basic geometric characteristics of  $m$ -th order uniform B-spline curves described below.

(iii) If it is determined that the  $m + 1$  vertices  $V_i = V_{i+1} = \dots = V_{i+m} = V$  of s-th spline segment  $P_s(t)$  coincide, then this segment degenerates into a point.

(iv) The segments are connected into  $c^{m-1}$  continuations, i.e.  $P_i^{(i)}(1) = P_{i+1}^{(i)}(0)$ ,  $i = 0, 1, \dots, m - 1$ .

From property (iii) we obtain  $P_i(t) = \sum_{j=0}^m f_{m,i}(t) \cdot V = V$ , and derive the normalization condition for the basic formula:

$$\sum_{j=0}^m f_{m,i}(t) = 1. \quad (3)$$

From property (iv) we obtain  $\sum_{j=0}^m f_{m,i}^{(i)}(1) \cdot V_{i+1} = \sum_{j=0}^m f_{m,i}^{(i)}(0) \cdot V_{i+i+1}$ ,  $i = 0, 1, \dots, m - 1$ .

Based on property (iv), the vector coefficients with the same subscripts on the two sides of the equality must be equal, and thus we find the following continuity conditions:

$$\begin{cases} 0 = f_{m,m}^{(i)}(0), & (4) \\ f_{m,i+1}^{(i)}(1) = f_{m,i}^{(i)}(0), \quad i, i = 0, 1, \dots, m - 1, & (5) \\ f_{m,0}^{(i)}(1) = 0, & (6) \end{cases}$$

Conditions (3)-(6) include a total of  $(m+1)^2$  equations which determine exactly  $(m+1)^2$  unknown coefficients.

On the basis of conditions (3)-(6), Clark in [1] derived the basic formulas for first- and second-order uniform B-splines, but he did not obtain the general formula for  $m$ -th order B-splines. We shall make this derivation from the same group of conditions.

## II. Derivation of Basic Functions

Conditions (4) and (6) indicate respectively that  $f_{m,m}(t)$  has exactly  $t = 0$   $m$ -fold zeroes and that  $f_{m,0}(t)$  has exactly  $t = 1$   $m$ -fold zeroes. Accordingly, we have

$$f_{m,m}(t) = a_{m,m}t^m, \quad a_{m,m} \text{ is unknown,}$$

and therefore

$$a_{i,m} = \begin{cases} 0, & i = 0, 1, \dots, m-1, \\ a_{m,m}, & i = m \end{cases} \quad (7)$$

and also

$$f_{m,0}(t) = a_{m,0}(t-1)^m = \sum_{i=0}^m (-1)^{m-i} a_{m,0} c_m^i t^i, \quad a_{m,0} \text{ where } a_{m,0} \text{ is unknown,}$$

so that

$$a_{i,m} = (-1)^{m-i} a_{m,0} c_m^i. \quad (8)$$

Differentiating equation (2) with respect to  $t$ , we derive

$$f_{m,i}^{(j)}(t) = \sum_{p=i}^m a_{p,i} \frac{p!}{(p-i)!} t^{p-i}. \quad (9)$$

Substituting  $t = 0$ , we obtain

$$f_{m,i}^{(j)}(0) = i! a_{i,i}, \quad (10)$$

Now substituting  $t = 1$  into equation (9) and replacing  $j$  by  $j+1$ , we obtain

$$f_{m,i+1}^{(j)}(1) = \sum_{p=i}^m a_{p,i+1} \frac{p!}{(p-i)!}. \quad (11)$$

From equation (5), the above two equations are equal, so that

$$a_{i,i} = \sum_{p=i}^m a_{p,i+1} c_p^i, \quad i, i = 0, 1, \dots, m-1. \quad (12)$$

Substituting  $j = m - 1$  into this equation, we obtain

$$a_{i,m-1} = c_m^i a_{m,m}; \quad i = 0, 1, \dots, m-1.$$

Then, substituting  $j = m - 2$  into equation (12) and applying the above equation, we obtain

$$\begin{aligned} a_{i,m-2} &= \sum_{p=i}^m c_p^i a_{p,m-1} = \sum_{p=i}^{m-1} c_p^i c_m^p a_{m,m} + c_m^i a_{m,m-1} \\ &= c_m^i \left[ \left( \sum_{p=i}^{m-1} c_{m-i}^{p-i} \right) a_{m,m} + a_{m,m-1} \right] \\ &= c_m^i [(2^{m-i} - 1^{m-i}) a_{m,m} + (1^{m-i} - 0^{m-i}) a_{m,m-1}] \\ &= c_m^i \sum_{k=0}^1 [(2-k)^{m-i} - (1-k)^{m-i}] a_{m,m-k}, \\ &\quad i = 0, 1, \dots, m-1. \end{aligned}$$

We shall prove by induction that if

$$\begin{aligned} a_{i,j+1} &= c_m^i \sum_{k=0}^{m-j-1} [(m-j-1-k)^{m-i} - (m-j-2-k)^{m-i}] a_{m,m-k}, \\ &\quad i = 0, 1, \dots, m-1, \quad j = 0, 1, \dots, m-2, \end{aligned} \quad (13)$$

then

$$\begin{aligned} a_{i,j} &= c_m^i \sum_{k=0}^{m-j-1} [(m-j-k)^{m-i} - (m-j-1-k)^{m-i}] a_{m,m-k}, \\ &\quad i, j = 0, 1, \dots, m-1, \end{aligned} \quad (14)$$

Replacing the  $i$  in hypothesis (13) by  $p$  and substituting into equation (12), we obtain

$$\begin{aligned} a_{i,j} &= \sum_{p=i}^{m-1} c_p^i c_m^p \sum_{k=0}^{m-j-1} [(m-j-1-k)^{m-p} - (m-j-2-k)^{m-p}] a_{m,m-k} + c_m^i a_{m,j+1} \\ &= c_m^i \sum_{k=0}^{m-j-1} a_{m,m-k} \left[ \sum_{p=i}^{m-1} c_{m-i}^{p-i} (m-j-1-k)^{m-p} \right. \\ &\quad \left. - \sum_{p=i}^{m-1} c_{m-i}^{p-i} (m-j-2-k)^{m-p} \right] + c_m^i a_{m,j+1} \\ &= c_m^i \sum_{k=0}^{m-j-1} a_{m,m-k} \{ [(m-j-1-k+1)^{m-i} - 1] - [(m-j-2-k \\ &\quad + 1)^{m-i} - 1] \} + c_m^i a_{m,j+1} \\ &= c_m^i \sum_{k=0}^{m-j-1} a_{m,m-k} [(m-j-k)^{m-i} - (m-j-1-k)^{m-i}] + c_m^i a_{m,j+1} \\ &= c_m^i \sum_{k=0}^{m-j-1} [(m-j-k)^{m-i} - (m-j-1-k)^{m-i}] a_{m,m-k}, \\ &\quad i, j = 0, 1, \dots, m-1. \end{aligned}$$

which completes the proof. Therefore,

$$\begin{aligned}
 \sum_{j=0}^m a_{i,j} &= \sum_{j=0}^{m-1} c_m^j \sum_{k=0}^{m-j-1} [(m-j-k)^{m-i} - (m-j-1-k)^{m-i}] a_{m,m-k} + a_{i,m} \\
 &= c_m^i \sum_{k=0}^{m-1} a_{m,m-k} \sum_{j=0}^{m-k-1} [(m-j-k)^{m-i} - (m-j-1-k)^{m-i}] + a_{i,m} \\
 &= c_m^i \sum_{k=0}^{m-1} (m-k)^{m-i} a_{m,m-k} + a_{i,m} \\
 &= c_m^i \sum_{j=1}^m j^{m-i} a_{m,j}, \quad i = 0, 1, \dots, m-1.
 \end{aligned} \tag{15}$$

Differentiating equation (3) with respect to  $t$ , we obtain

$$\sum_{j=0}^m f_{m,j}^{(i)}(t) = \begin{cases} 1, & i = 0, \\ 0, & i = 1, 2, \dots, m. \end{cases}$$

Substituting  $t = 0$  into the above equation and applying equation (10), we obtain

$$\sum_{j=0}^m a_{i,j} = \begin{cases} 1, & i = 0, \\ 0, & i = 1, 2, \dots, m. \end{cases} \tag{16}$$

Applying equation (15), we obtain from the above equation

$$\begin{cases} \sum_{j=0}^m a_{m,j} = 0, \\ \sum_{j=1}^m j^{m-i} a_{m,j} = 0, \quad i = 1, 2, \dots, m-1, \\ \sum_{j=1}^m j^m a_{m,j} = 1, \end{cases} \tag{17}$$

the first of these equations can be obtained from equation (16) by directly setting  $1 = m$ . Equation (17) is a group of linear equations:

$$\begin{bmatrix} 1 & 1 & 1 & \dots & 1 & \dots & 1 \\ 0 & 1 & 2 & \dots & j & \dots & m \\ 0 & 1 & 2^2 & \dots & j^2 & \dots & m^2 \\ \vdots & \vdots & \vdots & & \vdots & & \vdots \\ 0 & 1 & 2^m & \dots & j^m & \dots & m^m \end{bmatrix} \begin{bmatrix} a_{m,0} \\ a_{m,1} \\ a_{m,2} \\ \vdots \\ a_{m,j} \\ \vdots \\ a_{m,m} \end{bmatrix} = \begin{bmatrix} 0 \\ \vdots \\ \vdots \\ \vdots \\ 0 \\ \vdots \\ 1 \end{bmatrix}. \tag{18}$$



Using the Cramer method, the solution is

$$a_{m,j} = \frac{D_j}{D}.$$

Since

$$\begin{aligned} D &= \begin{vmatrix} 1 & 1 & 1 & \dots & 1 & \dots & 1 \\ 0 & 1 & 2 & \dots & j & \dots & m \\ 0 & 1 & 2^2 & \dots & j^2 & \dots & m^2 \\ \vdots & \vdots & \vdots & & \vdots & & \vdots \\ 0 & 1 & 2^m & \dots & j^m & \dots & m^m \end{vmatrix} = m! \begin{vmatrix} 1 & 1 & \dots & 1 & \dots & 1 \\ 1 & 2 & \dots & j & \dots & m \\ \vdots & \vdots & & \vdots & & \vdots \\ 1 & 2^{m-1} & \dots & j^{m-1} & \dots & m^{m-1} \end{vmatrix} \\ &= m!(m-1)!\dots 2!1!, \\ D_j &= \begin{vmatrix} 1 & 1 & 1 & \dots & 1 & & 0 & 1 & \dots & 1 \\ 0 & 1 & 2 & \dots & j-1 & & \vdots & j+1 & \dots & m \\ 0 & 1 & 2^2 & \dots & (j-1)^2 & & \vdots & (j+1)^2 & \dots & m^2 \\ \vdots & \vdots & \vdots & & \vdots & & 0 & \vdots & & \vdots \\ 0 & 1 & 2^m & \dots & (j-1)^m & & 1 & (j+1)^m & \dots & m^m \end{vmatrix} \\ &= (-1)^{m-j} \frac{m!}{j} \begin{vmatrix} 1 & 1 & \dots & 1 & & & 1 & \dots & 1 \\ 1 & 2 & \dots & j-1 & & & j+1 & \dots & m \\ \vdots & \vdots & & \vdots & & & \vdots & & \vdots \\ 1 & 2^{m-2} & \dots & (j-1)^{m-2} & & & (j+1)^{m-2} & \dots & m^{m-2} \end{vmatrix} \\ &= (-1)^{m-j} \frac{m!}{j} \cdot \frac{(m-1)!(m-2)!\dots 2!1!}{(j-1)!(m-j)!}, \end{aligned}$$

(see Ref [3] for details of the determinant calculation), therefore

$$a_{m,j} = (-1)^{m-j} \frac{1}{j!(m-j)!} = (-1)^{m-j} \frac{c_m^j}{m!}, \quad j = 0, 1, \dots, m. \quad (19)$$

Substituting equation (19) into equation (14), we obtain the general equation for the coefficients of the basic formula or for the matrix elements:

$$\begin{aligned} a_{i,j} &= c_m^i \sum_{k=0}^{m-j-1} [(m-j-k)^{m-i} - (m-j-1-k)^{m-i}] (-1)^k \frac{c_m^{m-k}}{m!} \\ &= \frac{c_m^i}{m!} \sum_{k=0}^{m-j-1} (-1)^k c_{m+1}^k (m-j-k)^{m-i}, \\ &= \frac{c_m^i}{m!} \sum_{k=0}^{m-j} (-1)^k c_{m+1}^k (m-j-k)^{m-i}, \quad i, j = 0, 1, \dots, m-1, \\ &\quad i, j = 0, 1, \dots, m. \end{aligned} \quad (20)$$

Now, substituting equation (20) into equation (2), we obtain the general formula

$$\begin{aligned}
 f_{m,j}(t) &= \frac{1}{m!} \sum_{i=0}^m c_m^i t^i \sum_{k=0}^{m-j} (-1)^k c_{m+1}^k (m-j-k)^{m-i} \\
 &= \frac{1}{m!} \sum_{k=0}^{m-j} (-1)^k c_{m+1}^k (m-j-k)^m \sum_{i=0}^m c_m^i \left( \frac{t}{m-j-k} \right)^i \\
 &= \frac{1}{m!} \sum_{k=0}^{m-j} (-1)^k c_{m+1}^k (m-j-k+t)^m, \\
 0 \leq t \leq 1, j=0, 1, \dots, m.
 \end{aligned} \tag{21}$$

Setting  $j = m$  in equation (19) and substituting into equation (7), then solving equations (7), (12) and (19) simultaneously, we obtain a group of recursion formulas for the junction coefficients or for the matrix elements

$$\begin{cases} a_{i,m} = \begin{cases} 0, & i = 0, 1, \dots, m-1, \\ \frac{1}{m!}, & i = m, \end{cases} \\ a_{i,j} = \sum_{p=i}^m c_p^i a_{p,j+1}, & i, j = 0, 1, \dots, m-1, \\ a_{m,j} = (-1)^{m-j} \frac{c_m^j}{m!}, & j = 0, 1, \dots, m. \end{cases} \tag{22}$$

From the same conditions (3)-(6) we can derive a different set of equations

$$a_{i,j} = (-1)^i \frac{c_m^i}{m!} \sum_{k=0}^j (-1)^k c_{m+1}^k (j-k+1)^{m-i}, \quad i, j = 0, 1, \dots, m, \tag{23}$$

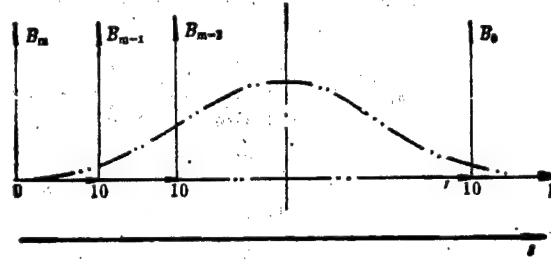
$$f_{m,j}(t) = \frac{1}{m!} \sum_{k=0}^j (-1)^k c_{m+1}^k (j-k+1-t)^m, \quad 0 \leq t \leq 1, j = 0, 1, \dots, m, \tag{24}$$

$$\begin{cases} a_{i,0} = (-1)^i \frac{c_m^i}{m!}, \\ a_{i,i} = (-1)^{i-i} \frac{c_m^i c_m^i}{m!} + \sum_{k=i}^{m-1} (-1)^{i+k} c_k^i a_{k,i-1}, \\ i = 0, 1, \dots, m, j = 1, 2, \dots, m. \end{cases} \tag{25}$$

These equations are of the same character as the set of equations (20)-(22) and reflect the symmetry of the basic junctions. Indeed, if we replace  $j$  in the right side of either formulas (21) or (24) by  $m-j$  and replace  $t$  by  $1-t$ , we obtain the right side of the other equation.

If we successively connect equations (21) or (24) as shown in equations (4)-(6), we obtain an  $m$ -th order normalized uniform B-spline defined piecewise on  $[0, 1]$ , as shown in Figure 1. If  $m$  is ~~3~~ odd, the symmetry axis is located at the adjacent point of the junction of the two centermost areas, while if  $m$  is even, then it is located halfway through the central area.

Figure 1.



### III. Properties and Computation Formulas

Based on the basic function expressed in general formula (21) or (24) we readily obtain the following properties and computation formulas.

#### A. Recursion formula for basic function

$$\begin{cases} f_{m,i}(t) = \frac{j+1-t}{m} f_{m-1,i}(t) + \frac{m-j+t}{m} f_{m-1,i-1}(t), & m \geq 1, j = 1, 2, \dots, m, \\ f_{0,0}(t) = 1, \end{cases} \quad (26)$$

with the condition that if  $i < 0$  or  $i > m$ , then  $f_{m,i}(t) = 0$ .

#### B. Recursion formula for derivative of basic function

$$\begin{cases} f_{m,i}^{(j)}(t) = f_{m-1,i-1}^{(j-1)}(t) - f_{m-1,i}^{(j-1)}(t), & i = 1, 2, \dots, m, j = 0, 1, \dots, m, \\ \text{with the condition that if } j < 0 \text{ or } j > m, \text{ then } f_{m,i}^{(j)}(t) = 0, & i = 0, 1, \dots, m. \end{cases} \quad (27)$$

#### C. Symmetry equation

$$\begin{cases} f_{m,i}^{(j)}(t) = (-1)^j f_{m,m-i}^{(j)}(1-t), & i = 0, 1, \dots, m, \\ a_{i,j} = (-1)^j a_{i,m-j-1}, & i, j = 0, 1, \dots, m-1. \end{cases} \quad (28)$$

#### D. Recursion formula for position vector of uniform B-spline curve

$$\begin{cases} P_i(t) = \sum_{j=0}^{m-p} f_{m-p,j}(t) \cdot V_{i+j}^{(p)}(t), & p = 0, 1, \dots, m, \\ V_{i+j}^{(p)}(t) = \frac{j+1-t}{m-p+1} V_{i+j}^{(p-1)}(t) + \frac{m-j-p+t}{m-p+1} V_{i+j+1}^{(p-1)}(t), \\ & p = 1, 2, \dots, m, j = 0, 1, \dots, m-p, \\ V_{i+j}^{(0)}(t) = V_{i+j}, & i = 0, 1, \dots, m, \end{cases} \quad (29)$$

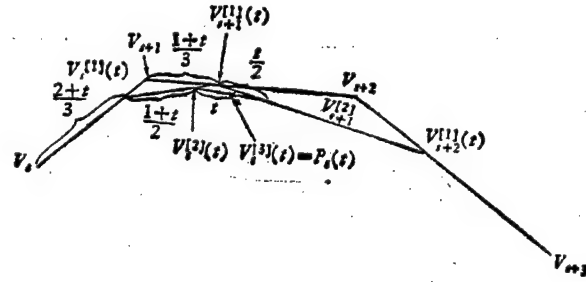
The second of these formulas is shown in Figure 2.

$$\underbrace{(y)_{(1-t)A}^{(j)+1} \cdot (t)_{(t)A}^{(j)+1}}_{\frac{1+d-u}{t+d-t-u}}$$

Based on equation (29), we can use the geometric plotting method to determine which point  $P_s(t)$  in the spline curve (1) has the coefficient  $t$ : obviously,

$$P_s(t) = V_{s+j}^{(m)}(t).$$

Figure 3.



Example. If the vertices  $\{V_i\}_{i=0}^{n+m}$ ,  $m=3$ , of a B-characteristic polygon are specified, then we define one section of a third-order uniform B-spline curve  $P_s(t)$ . If we need to determine the point on the curve whose coefficient is  $t$ , we can do so from the following plot (Figure 3), taking  $t = 1/2$ .

E. One recursion formula for the uniform B-spline derivative vector, the "fast end" curve

$$\begin{cases} P_s^{(p)}(t) = \sum_{j=0}^{m-p} f_{m-p,j}(t) \cdot V_{s+j}^{(p)}, & p = 0, 1, \dots, m, \\ V_{s+j}^{(p)} = V_{s+j+1}^{(p-1)} - V_{s+j}^{(p-1)}, & p = 1, 2, \dots, m, j = 0, 1, \dots, m-p, \\ V_{s+j}^{(0)} = V_{s+j}, & j = 0, 1, \dots, m \end{cases} \quad (30)$$

The difference between this formula and equation (29) is that  $V_{s+j}^{(p)}$  is unrelated to a parameter  $t$  but is equivalent to the side vector of the polygon obtained above for  $p-1$  recursions,  $V_{s+j+1}^{(p-1)} - V_{s+j}^{(p-1)}$ . From equation (30) we can calculate the  $p$ -th order  $(1, 2, \dots, m)$  for the point with parameter  $t$ . Obviously, the  $m$ -th derivative vector  $P_s^{(m)}(t) = V_{s+j}^{(m)}$  is a constant vector.

F. A second recursion formula for the derivative of the uniform B-spline curve.

To avoid confusion, we use the following alternative writing of the left side of equation (1):

$$P_{m,s}(t) = \sum_{j=0}^m f_{m,j}(t) \cdot V_{s+j}, \quad 0 \leq t \leq 1, s = 1, 2, \dots, n,$$

This indicates an  $m$ -th order uniform B-spline curve specified by vertices  $\{V_i\}_{i=1}^{n+m}$  containing  $n$  segments. An  $(m-p)$ -th order uniform B-spline curve defined by the same vertices is

$$P_{m-p,s}(t) = \sum_{j=0}^{m-p} f_{m-p,j}(t) \cdot V_{s+j}, \quad 0 \leq t \leq 1, s = 1, 2, \dots, n+p,$$

and contains  $n+p$  segments. Then the following recursion relation holds:

$$P_{m,s}^{(p)}(t) = P_{m-1,s+1}^{(p-1)}(t) - P_{m-1,s}^{(p-1)}(t), \quad 0 \leq t \leq 1, \\ p = 1, 2, \dots, m, \quad s = 1, 2, \dots, n.$$

This expresses the relationship between the uniform B-splines of all orders determined by the same B-characteristic polygon.

It should be pointed out that equations (26), (29) and (30) correspond to the de Beer-Cox recursion formulas. There is no need to cite the other well known properties and computation formulas.

This article was completed under the guidance of our teacher, Wu Junheng [0702 7486 1854]. During the writing of the manuscript we received enthusiastic assistance from Comrades Xu Shuxian [1776 0647 6343] and Juang Zhiquan [6782 1807 3123] of the Institute of Mechanics, CAS; we take this occasion to express our thanks.

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8480/8918

CSO: 4008/1014

APPLIED SCIENCES

NUCLEAR FUSION DEVICE PASSES APPRAISAL TEST

OW201210 Beijing XINHUA in English 1139 GMT 20 Nov 85

[Text] Chengdu, 20 Nov (XINHUA)--A Chinese device being used by scientists in a bid to harness the sun's method of producing energy passed a technical appraisal test at Leshan, Sichuan Province, this week.

The device, called HL-1, which went into operation at Leshan's Southwest Physics Institute in September last year, has proved satisfactory in all experiments so far conducted, 70 scientists who attended the appraisal meeting agreed.

They said this success marked an important step in China's research into nuclear fusion power.

Scientists in many countries are trying to produce energy through the controlled fusion of hydrogen atoms.

This happens on the sun, and to do it on earth, very high temperatures and powerful electromagnetic fields are required.

The development of nuclear fusion power could give the earth a practically inexhaustible source of energy, because sea water abounds in fusion fuel.

Qian Shangjie, deputy director of the Southwest Physics Institute, said scientists there would use the approved device to continue their research and to train personnel.

They also hoped to expand co-operation and technical exchanges with foreign colleagues. Since 1984, 250 nuclear fusion experts from Australia, Federal Germany, France, Italy, Japan, and the United States had visited the institute.

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CSO: 4010/13

APPLIED SCIENCES

PASSIVE MODE-LOCKING OF AN XeCl\* EXCIMER LASER

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 5 No 7, Jul 85  
pp 643-647

[Article by Cheng Xusan [2052 1645 0005], Lou Qihong [2689 4388 3163] and Wang Runwen [3769 3387 2429], Shanghai Institute of Optics and Precision Mechanics, CAS]

[Text] Abstract. Mode locking of an XeCl\* excimer laser was achieved with naphthalene and PPT for the first time, using a simple, compact "soft focus" light path; a pulse width of 3 ns, over 90 percent modulation, a total output energy of 6.3 mJ, and a spatial divergence angle of 2 mrad in a pulse train of 4 to 5 distinct 3-ns spikes was obtained.

XeCl\* excimer lasers have attracted considerable interest because of their long operating life, high output power, and ability to radiate in the ultraviolet region. But currently most of the devices pumped by transition and inversion discharges have pulse widths of 15 to 60 ns. Many special applications (optical chemistry, spectroscopy and relaxation time measurements) [1] require somewhat shorter pulse widths. One method of obtaining short ultraviolet pulses is to use a dye laser for mode locking, together with amplification and frequency doubling, which yields picosecond-range ultraviolet pulses [1], but these require a complicated system. Another method is to use a fast-discharge excimer laser to obtain pulses several ns long; if a saturated absorber is used, it is possible to compress the pulses further to sub-nanosecond length [2], but this method is suited only to certain special devices. For some short-pulse excimer lasers, active mode locking [3,4] and passive mode locking [5,6] are effective ways of obtaining short pulses; the passive mode locking devices are simpler.

We used a freely oscillating XeCl\* excimer laser with a flat-plate discharge, having a single pulse power of 800 mJ and an 80 gain, combined with three different dyes to obtain mode-locked pulse trains of 4 to 5 distinct 3-ns peaks.

I. Experimental Apparatus

The light path used in the experiment is shown in Figure 1.  $M_1$  is a completely reflective mirror with a radius of curvature of 2 m.  $M_2$  at the forward window of the dye cell is a two-sided mirror 1 mm thick with an antireflective film

(reflectivity less than 2 percent for normal incidence) made from a quartz plate, which is parallel to  $M_1$ .  $M_5$  is a partially reflective output coupling mirror.  $M_3$  and  $M_4$  are quartz flats used as windows for the discharge chamber (uncoated); they are tilted at an angle exceeding  $18^\circ$  in order to prevent spurious oscillations from arising. The laser waveform was received by a Chinese-produced GD-10 high-current photocell connected to an oscilloscope. In order to make the photomultiplier operate in the nearly linear region, we used different attenuations for laser pulses of different intensities. In the case of Figure 1a we used several  $K_9$  glass plates and quartz glass plates coated with films of various reflectivities as attenuators to prevent saturation of the photocell. The energy was measured with a pulsed laser energy meter behind the uncoated quartz beam-splitting plate. Experimental comparisons indicated that this light path for passive mode locking was simple, compact and rather effective. The feedback and cyclic loss mechanism of the mode-locked light were regulated by the thickness of the dye chamber, the concentration of the dye, the cavity length, and the reflectivity of the output coupling mirror  $M_5$ .

Three different dyes were used in the experiment: DPBD (2-(4'-terbutylphenyl)-5-(4"-biphenyl)-1, 3, 4-oxadiazole), naphthalene, and PTP (p-terphenyl).

Because the 3 dyes have a very high saturated absorption intensity at 3080 Å, Ref 5 reports the addition of a focusing mirror inside the cavity in order to increase the light intensity density in the dye cell, as shown in Figure 1b, and concludes that it is the key to mode locking with the DPBD and BBQ dyes. In our experiments we did not place a lens inside the cavity, but instead used a "soft focus" output coupling mirror  $M_5$ . With a cavity length of  $L = 1.6$  m, we used for  $M_5$  a convex reflective quartz glass cavity plate (with an 80 percent reflective coating) having a radius of curvature of 3 m and a reflective focal length of  $f = 1.5$  m near the dye cell to produce a soft focus; this increased the pulse power density entering the dye chamber and increased non-linear saturated absorption of mode-locked pulse trains by the dye.

## II. Results and Discussion

Several scintillators used in nuclear counters were used as the saturable absorption medium for passive mode locking with the  $\text{XeCl}^*$  laser. Most of these scintillators (below referred to as the dyes) had a strong absorption peak in the ultraviolet and a high saturation absorption intensity, as well as an upper level relaxation time in the nanosecond range. The absorption characteristics for BBQ, BPBD and PTP at 3080 Å are given in Refs 2 and 5.

### A. Effect of Dye Concentration

The laser waveforms obtained with the optical path of Figure 1 for mode locking with naphthalene at different concentrations in cyclohexane are shown in Figures 2a and b. With the optical path of Figure 1b, mode locking with naphthalene in cyclohexane gave the waveform shown in Figure 2c. The total output energies for Figures 2a, b and c are 3, 6.5 and 2 mJ respectively. Obviously the optical path without the lens (Figure 1a) is superior to that with the lens (Figure 1b). The reasons may be as follows: first, the presence



of the lens in the cavity produces needless losses and decreases the energy output; second, adding another optical component to the cavity adds two more optical surfaces to produce parasitic-oscillation feedback, and in such a high-energy, long gain region (high unit-path gain) device as the  $\text{XeCl}^*$  laser, any parasitic feedback, no matter how small, will be magnified greatly in each unit path length, causing the signal-to-noise ratio to fall.

In experiments where the power density of the components is rather high, placing a lens in the cavity is likely to damage the optical components. This is because under ideal conditions the lens should be placed in the focal plane of  $M_1$ ; otherwise, after the reflected light passes through the lens it will not be transformed from a spherical wave to a plane wave, and thus beam divergence will result. But if it is focused, the high-power converging light concentrated at the central focal point of mirror  $M_1$  can exceed  $10^7 \text{ W/cm}^2$ , so that  $M_1$  is likely to be damaged (particularly its fully reflective coating). Because the dye cell is also thin, window  $M_2$ , which is very close to the focal point, will also be damaged.

Naturally, for some components with insufficient gain, when the peak laser power is less than the saturated absorption power of the absorber, use of a concentrating lens can increase the power density in the dye near the focal point, thereby increasing the saturated transmissivity effect in the nonlinearly absorbent dye and yielding good mode locking results. Because the gain in the components used in the present experiment is sufficiently high, it was preferable not to use the lens.

#### B. Beam Directionality

We also investigated the directionality of the mode-locked pulse beam, determining the divergence by the focal spot method. The experiment indicated that the optical path containing a lens (Figure 1b) had a divergence of up to 10 mrad, while without the lens (Figure 1a) the divergence was less than 2 mrad, a spatial divergence as good as for the non-mode-locked laser. Another reason for the good beam directionality is that the window  $M_2$  of the dye cell, is perpendicular to the cavity axis, so that no path difference is produced by the refractive index, which would result in bending of the parallel light. In general, the dye cell windows described in Refs 5 and 6 were tilted in order to prevent  $M_2$  from feeding back the noise signal that had not undergone nonlinear compression in the absorber to the cavity where it would be amplified and would decrease the depth of modulation. Our experiments indicated that provided both sides of  $M_2$  were coated with sufficiently high-transmissivity film (e.g. producing a reflectivity of less than 2 percent), having mirrors  $M_2$  and  $M_1$  parallel would not cause a decrease in the depth of modulation, while the beam directionality would be improved.

#### C. Effect of Dye Cell Thickness

The experiments with BPBD and PTP solutions in alcohol and with naphthalene in hexane all produced mode locking\* (see Figures 2, 3 and 4). We found that it

\*Ref 5 reports that mode locking was not observed with PTP and concludes that this is because the saturated absorption light intensity was too great.

was not necessary to have a concentrating lens in the optical circuit: the key is to adjust the dye cell thickness and dye concentration (e.g. for a dye with too great an absorptivity the concentration can be suitably decreased) with reference to the dye's absorptivity so that it is matched to the components used for mode locking in order to achieve good mode locking effectiveness. With a given gain, the extinction coefficient per gram-molecular weight of dye is

$$\epsilon = \frac{1}{NL} \ln \frac{I_0}{I},$$

where  $I_0$  is the incident light intensity and  $I$  is the transmitted light intensity,  $L$  is the length through the dye, and  $N$  is the dye concentration. Thus the optimum dye concentration is inversely proportional to the optimum dye reservoir thickness, and accordingly the gain factors of the specific components must be taken into account along with all other factors.

The main reasons that mode locking was obtained with PTP in our experiments were: (1) the peak power of the component used was high; (2) no focusing lens was included in the optical path, but a "soft focus" output coupling lens was used instead, increasing the peak power density within the dye reservoir and avoiding a drop in the intracavity peak power produced by the lens. As a result of these two factors, the components maintained a sufficiently high peak power to overcome the high saturated absorption intensity of PTP.

#### D. Effect of Cavity Length on Mode-Locked Pulses

The absorption recovery times (directly proportional to the upper energy level relaxation time) of the three dyes used as saturated absorbers were a few nanoseconds, and most of the excimer components had a cavity length of about 1 m, so that the round-trip time of the light within the cavity was of the same order of magnitude as the upper energy level relaxation time. Thus the three dyes used were in the critical area between fast absorbers [8] and slow absorbers [9], the full width of a mode-locked pulse pseudopeak was a few nanoseconds, and therefore the cavity length had some influence on the degree of modulation of the mode-locked pulse. Figure 4 shows mode-locking waveforms for BPBD in alcohol with cavity lengths of 1.2, 1.6 and 2.6 m, using a quartz plate of 80 percent reflectivity as a coupler. Under these experimental conditions the cavity length of 1.6 m (transit time about 10 ns) was best. For a longer cavity, the losses increased and the peak power accordingly decreased, so that the mode-locking results were degraded (see Figure 4c). When the cavity was shorter, each separate mode-locked peak had a distinct tail [8], and when the cavity length was such that the tail of the preceding peak was superimposed on the following peak there was a pronounced decrease in the degree of modulation (Figure 4a).

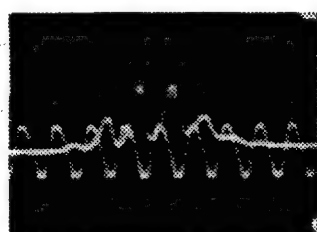
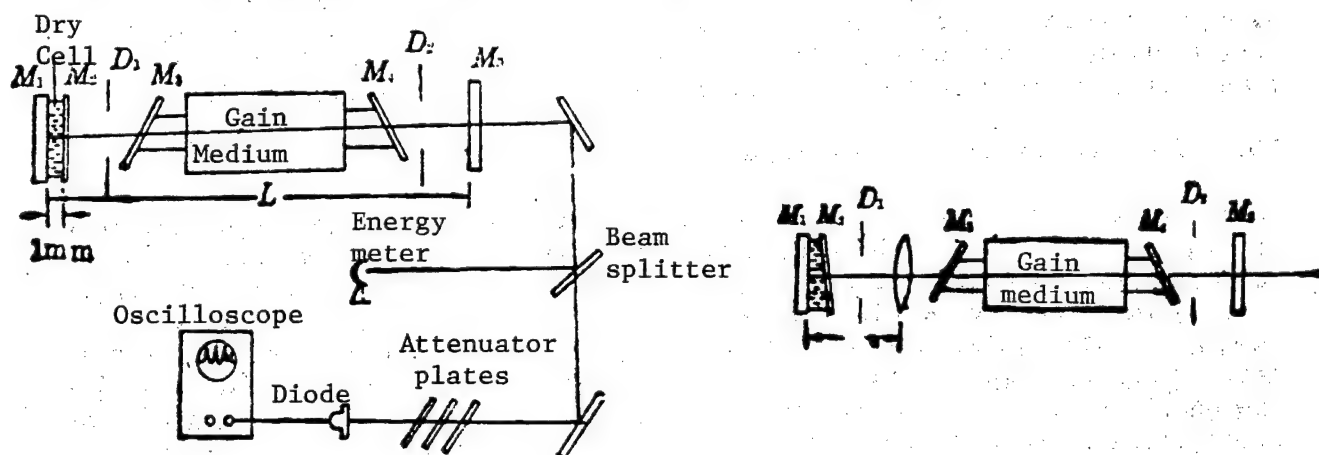
### III. Brief Conclusions

To summarize, by using passive mode locking a saturable absorber, we obtained a mode-locked output from an XeCl laser with a modulation factor exceeding 90 percent, a pulse width of 3 ns, a total power of 6.3 mJ, and a beam divergence of less than 2 mrad. The optical path used had the following characteristics:

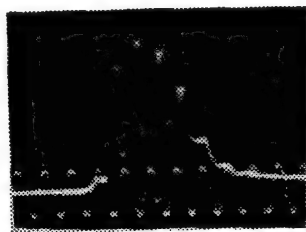
(1) it was simple and compact with a high output energy; (2) it dispensed with the use of a lens for in-cavity focusing in the mode-locking optical path, which could have damaged the optical components; (3) use of a "soft focus" output coupler matched to the cavity length increased the laser power density in the dye cell, thus overcoming the problem of the dye's high saturated absorption power; (4) a dye cell window coated with a high-transmissivity dielectric film, mounted perpendicular to the optical axis, increased the spatial quality of the beam and avoided an increase in divergence. In addition, this is the first report of the use of PTP and naphthalene for passive mode locking with an XeCl laser.

Trainee Xu Xiangdong [1776 0686 2639] of the Nanjing Academy of Mechanics took part in some of the experiments; Comrades Xu Chunliang [1776 4783 5328] and Si Qiming [2448 0796 2494] of the Shanghai No 1 Reagents Plant provided us with the dyes; and Comrade Wang Xiufen [3769 4423 5358] of the Shanghai Institute of Optical Instruments produced high-quality ultraviolet antireflective coatings for us. We take this occasion to express our deep gratitude.

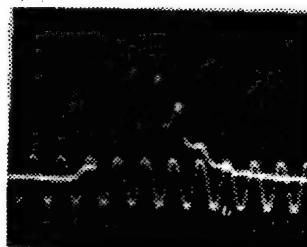
Figure 1. Setup of passive mode locking experiment



(a)  $10^{-3} \text{ M/l}$



(b)  $4 \times 10^{-4} \text{ M/l}$



(c)  $2 \times 10^{-3} \text{ M/l}$

Figure 2. Passive mode locking pulse trains, naphthalene in cyclohexane

Figure 3.

Passive mode locking pulse train, PTP  
in ethanol ( $2 \times 10^{-4}$  mol/l; time  
scale 10 ns)

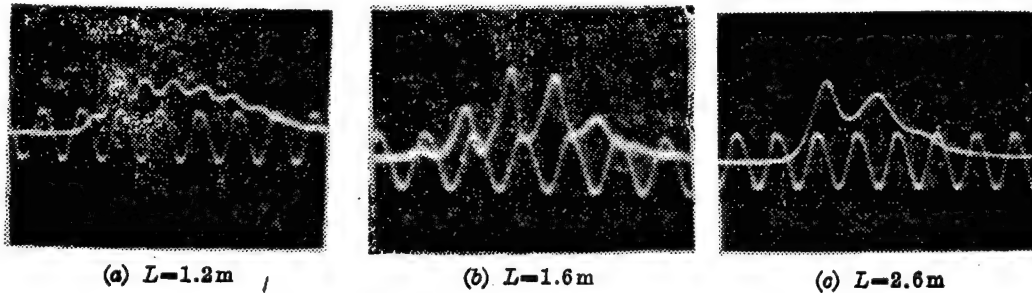
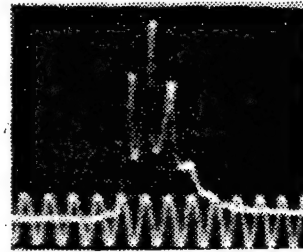


Figure 4. Passive mode locking pulse trains for various cavity lengths  
(BPDB in ethanol,  $8 \times 10^{-4}$  mol/l; time scale 10 ns)

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APPLIED SCIENCES

A COUMARIN C<sub>102</sub> DYE LASER PUMPED BY A 308-NM XeCl LASER

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12 No 8,  
20 Aug 85 pp 476-477

[Article by Shangguan Cheng [0006 1351 6134], Lin Yingyi [2651 5391 0308],  
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tute of Optics and Precision Mechanics, CAS; and Chen Bili [7115 1084 4539],  
Changchun Academy of Optics and Precision Mechanics; manuscript received  
20 June 1984]

[Text] Abstract. An experimental study of a coumarin  
C<sub>102</sub> tunable dye laser pumped by a 308-nm XeCl excimer  
laser is described. The tuning range is from 4605 to  
5010 Å and the tuning linewidth is about 1 Å.

Tunable dye lasers obtained by pumping with excimer lasers already cover a wide  
area of the spectrum, from 3200 Å to 1 μm.<sup>1,2</sup> They have extensive application  
prospects in laser chemistry, laser isotope separation and laser spectroscopy.  
Here we describe an experimental study of a tunable blue-green laser obtained  
by pumping coumarin 102 (C<sub>102</sub>) with an XeCl excimer laser.

Experimental Apparatus

The experimental apparatus is shown in Figure 1. The pumping source is an  
ultraviolet preionization avalanche discharge XeCl excimer laser<sup>3</sup> with an out-  
put wavelength of 308 nm and a spot size of 21 x 5 mm<sup>2</sup>. C is a quartz dye cell  
with a gain length of 15 mm whose two output windows are at an angle of 85° to  
the pumping window. CL is a quartz cylindrical lens with a focal length of  
5 cm. G is a holographic grating with 1,200 lines per mm, 5 cm wide, on which  
the dye laser output is incident at a large glancing angle, so that it pro-  
duces both dispersion and beam broadening. M<sub>1</sub> and M<sub>2</sub> are aluminum-plated  
fully reflective mirrors; rotation of M<sub>2</sub> modulates the dye laser. The dye  
laser has a cavity length of about 23 cm. SP is a 1-m flat grating spectro-  
graph whose grating was 1,200 lines/mm and a blaze wavelength of 5000 Å.

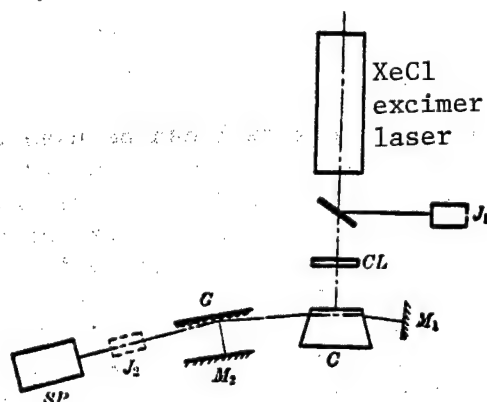


Figure 1. Glancing Angle Grating Tuning Apparatus

## Experimental Results and Discussion

### 1. Excitation Spectrum and Fluorescence Spectrum

Coumarin C<sub>102</sub> was synthesized by the institute's laser dye group<sup>4</sup>; its excitation spectrum and fluorescence spectrum are shown in Figure 2, as determined with a Japanese model 650-60 fluorescence spectrograph. Curve 1 is the excitation spectrum, with two peaks: one in the visible region at 432 nm and the other in the ultraviolet at 330 nm. It is evident from the figure that the 308 nm XeCl excimer laser is quite close to the UV peak for the excitation spectrum, which suggests that the XeCl excimer laser pumping would produce very strong fluorescence and thus that such a laser would be a good pumping source for C<sub>102</sub>. Curves 2 and 2' are fluorescence curves obtained for the 432 nm and 330 nm laser output, respectively. They differ only in intensity; the wavelength regions that they cover are nearly the same. Accordingly, by using lasers with outputs at the two peaks of the excitation spectrum, we could obtain tunable lasers with similar wavelength ranges.

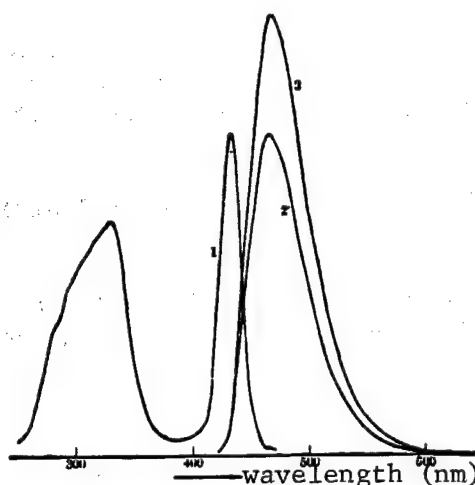


Figure 2. Lasing Spectrum and Fluorescence Spectrum of Coumarin C<sub>102</sub> in Ethanol

## 2. Fluorescence Spectrum, Lasing Spectrum and Tunable Laser With XeCl Laser Pumping

The experimental apparatus shown in Figure 1 can be used to tune the dye laser. The dye concentration used was  $5 \times 10^{-3}$  M/l. Ethanol was used as a solvent. The dye laser was tuned by rotating mirror  $M_2$ . The glancing angle on the grating was  $85.6^\circ$ ; because the efficiency of the grating used was rather low, the glancing angle could not be increased further, which affected the linewidth of the tunable laser. We used the spectrometer to determine the tunable laser's spectrum, under the following conditions: narrow peak width  $5 \mu\text{m}$ , distance from spectrometer to dye laser about 4 m in order to decrease the effect of superradiation. Figure 3 is a photograph of the tunable laser spectrum; the eight tuning spectra are numbered from top to bottom. The number of exposures for the lines are, respectively: 10, 2, 2, 2, 5, 10, 20, 50. The tuning range obtained from the tuning spectrum is  $405 \text{ \AA}$ , from  $4605$  to  $5010 \text{ \AA}$ . The measured tunable laser linewidth is about  $1 \text{ \AA}$ . Obviously, the tuning linewidth is insufficiently narrow. This is caused by various factors: the glancing angle at the grating, the dye laser cavity length, the quality of the tuning components (grating and reflective mirror) and the like.

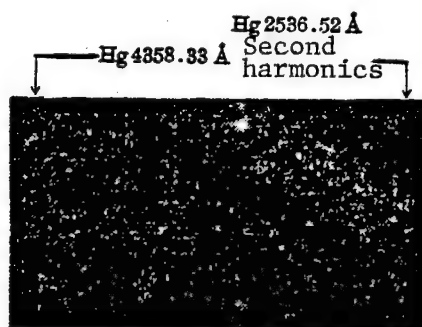


Figure 3. Photograph of Lasing Spectrum of  $C_{102}$  Dye Laser Pumped by XeCl Excimer Laser

When the wavelength of the peak in the fluorescence spectrum is close to the tuning wavelength, because of the large gain there generally occurs multimode (longitudinal mode) competition, with the result that doublet lines appear in the tuning spectrum.

The conversion rate of the tunable laser measured at the center of its fluorescence spectrum was about 9.2 percent.

We thank Comrades Wu Zhengliang [0702 2973 0081], Shu Juping [5289 5468 0988], Xu Ming [1776 2494], Qi Changhong [4359 7022 7703], and Shen Guirong [3088 2710 2837] for their help.

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APPLIED SCIENCES

CHARACTERISTICS OF LARGE-VOLUME X-RAY PREIONIZED XeCl EXCIMER LASER

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 12 No 8, 20 Aug 85 pp 468-470

[Article by Lou Qihong [2869 4388 3163], Cheng Xusan [2052 1645 0005], Ding Aizheng [0002 1947 5271], Wei Yunrong [7614 6663 2837], Ding Zean [0002 3419 1344] and Zheng Cheng'en [6774 2110 1869], Shanghai Institute of Optics and Precision Mechanics, CAS; manuscript received 25 September 1984]

[Text] Abstract. The characteristics of a large-volume XeCl excimer laser, including improved uniformity of X-ray preionization and unstable cavity output, were studied experimentally. A maximum pulse energy of 1.6 J was obtained.

In Ref. 1 we reported the operating characteristics of an 0.2-liter XeCl excimer laser with an X-ray preionized pulsed avalanche discharge. Below we describe the characteristics of a large-volume X-ray preionized XeCl laser developed from the initial small-volume discharge. In general, increasing the discharge volume can increase the requirements imposed on the preionization source and increase the circuit inductance. The experimental results indicated that provided the inductance does not exceed 0.1  $\mu$ H, the laser efficiency is not significantly decreased.

Selection of the optimum mixing ratio for the large-volume discharge and the optimum delay between X-ray preionization and the main discharge resulted in a large-volume discharge laser output energy of 1.6 J. We then proceeded with experiments on unstable cavity output which gave an improvement of an order of magnitude in the directionality compared with ordinary stable cavities, while the output energy was as high as 85 percent of the stable cavity value. Because most fast-discharge excimer lasers have output spots with a rectangular cross section, it is difficult to use a telescope-type unstable cavity structure. In our experiments we achieved a uniform discharge with a cross section of 3 x 3 cm<sup>2</sup> and a relatively satisfactory unstable cavity output.

#### I. Obtaining a Large-Volume Uniform Discharge

Because X-ray preionized XeCl excimer laser, when the gap between the electrodes is increased from 2 cm to 3 cm and the discharge breadth is increased

accordingly, it is somewhat difficult to obtain a uniform glow discharge, and an arc discharge is particularly likely to occur at the two edges of the electrodes. This may be because the planar form of the electrodes is not sufficiently uniform at their two edges or because the X-ray preionization dose there is too small.

Our experimental analysis of the cathode structures indicates that different cathode arrangements have different dose distributions. Accordingly, we used a cathode structure for which the dose distribution along the length of the discharge varied by less than a factor of 4. Figure 1 shows the average dose distributions for multiple pulses; the maximum exceeds the minimum by less than 100 percent. For comparison, the plot also shows the dose distribution for a point X-ray source.

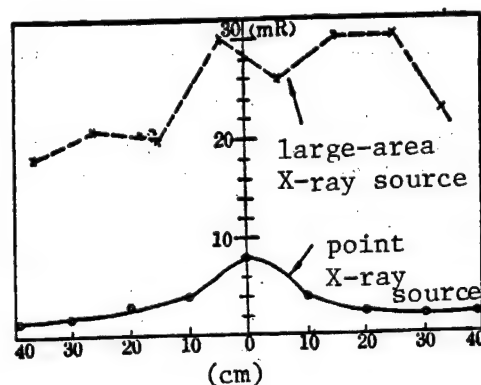


Figure 1. Distribution of X-ray Dose Along Length of Laser Tube

Following modifications, the X-ray dose distribution met the requirements for a large-volume uniform discharge. We then studied the effect of the delay time  $\tau_d$  on the laser output power for different discharge volumes but similar mixing ratios. It is evident from Figure 2 that the two characteristics vary in a similar way, and the optimum delay time  $\tau_d$  of the main discharge relative to the preionization is about 0.8  $\mu$ sec. The difference is that the large-volume discharge is more sensitive than a small-volume discharge to the effects of the delay time. On the other hand, this also reflects the heightened requirements regarding X-ray preionization intensity for large-volume uniform discharges.

In view of the facts we varied the gas mixing ratio and gas pressure to obtain the maximum output energy. Figure 3 shows the effect of different HCl concentrations on laser output for a total gas pressure of 5 atm and an Xe partial pressure of 30 Torr. It is evident that the optimum HCl concentration is about 1:1000. When the total gas pressure rises above 5 atm, the maximum output energy is 1.6 J; at this time the mixing ratio is HCl:Xe:Ne = 0.9:10:989.1. Figure 4 shows that with different main discharge capacitor charging voltages, the changes in the laser output energy are different from those in a small-volume gas discharge: at high voltages the laser output energy does not increase in linear fashion as the discharge voltage rises, but displays a

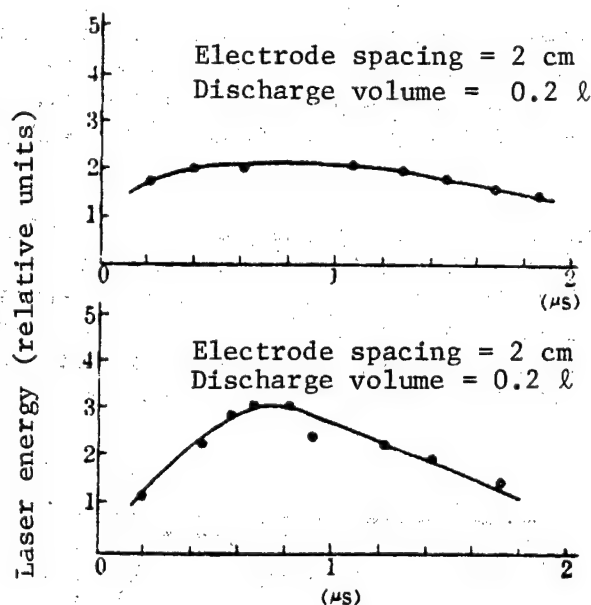


Figure 2. Effect of Delay Time  $\tau_d$  on Laser Output Energy for HCl Concentration of 0.12 Percent and Total Gas Pressure of 4 Atmospheres

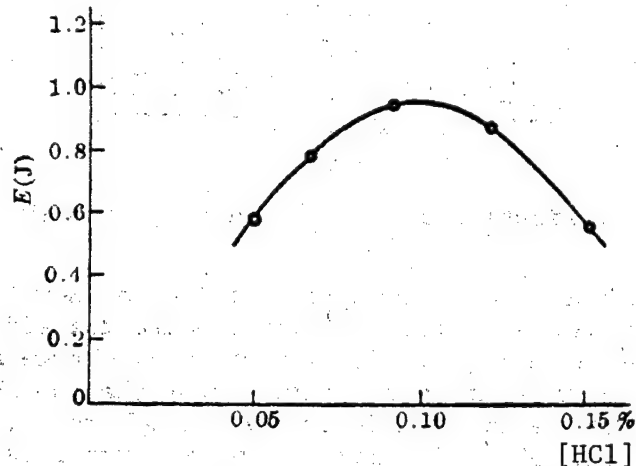


Figure 3. Effect of HCl Concentration on Laser Output Energy

certain tendency toward saturation. An analysis of discharge conditions indicates that this is related to the uniformity of the discharge.

## II. Use of Unstable Resonator To Improve Beam Quality

Because XeCl excimer lasers have a high gain, in stable cavity with a length of 1 m the use of a fully reflective mirror with a radius of 2-5 m together with a quartz plate to form the resonator generally produces a beam divergence greater than 20 mrad. In order to improve beam directionality, we used a confocal unstable cavity with  $M = 3.33$ , obtaining a cavity length of 1.05 m; the cavity consisted of a completely reflective mirror 30 mm in diameter with a radius of curvature of 3 m and a completely reflective mirror 9 mm in diameter with a radius of curvature of -0.9 m. Annular output coupling was

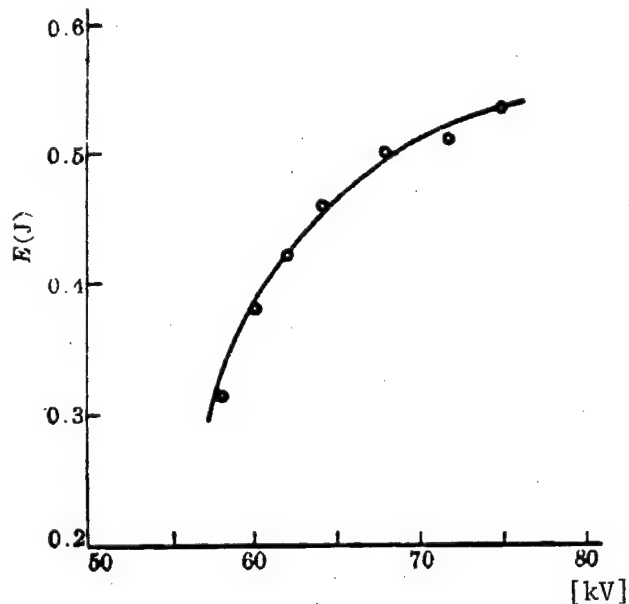


Figure 4. Laser Output Energy vs Voltage of Main Discharge

used. The entire laser device had a half out-of-cavity structure; one end was a fully reflective mirror while the other was a quartz window both sides of which were coated with a film having high transmissivity at  $3080 \text{ \AA}$ , with a convex lens 9 mm in diameter placed outside the cavity in order to allow precise adjustment of the cavity length and to make the cavity confocal.

The output spot for the unstable cavity was a 3 cm x 3 cm square for the near field, with no laser output in a central area 9 mm in diameter; the far-field distribution was a uniform rectangle. Figure 5 compares the laser output energy for a stable cavity and an unstable cavity. The abscissa gives the gas pressure for the rail gap switch of the main discharge circuit. In our experimental apparatus, in order to give the discharge voltage a rather rapid rise time, we placed a rail gap switch (also called a multi-channel switch) between the water-dielectric transmission line and the laser; the higher its breakdown voltage, the faster the discharge voltage rise time.<sup>3</sup> Details of the construction and action of the rail gap switch are found in Ref. 2. By suitably increasing the switch's gas pressure it is possible to increase the stability of the discharge, because a rather large breakdown voltage can increase the discharge current at the same rate until the inductance of the discharge circuit causes the discharge voltage to fall. Conversely, a rather low breakdown voltage can result in a quite slow breakdown process, and the current rise time will be limited by the ionization rate and not the inductance, so that discharge initiation will be nonuniform and the discharge will pass over into arcing. It can be seen from the comparison in Figure 5 that in most cases the laser energy of an unstable cavity is 70 percent or more of that of a stable cavity, and that as the gas pressure inside the rail gap switch is increased, the laser output energy from the unstable cavity can increase to 85 percent.

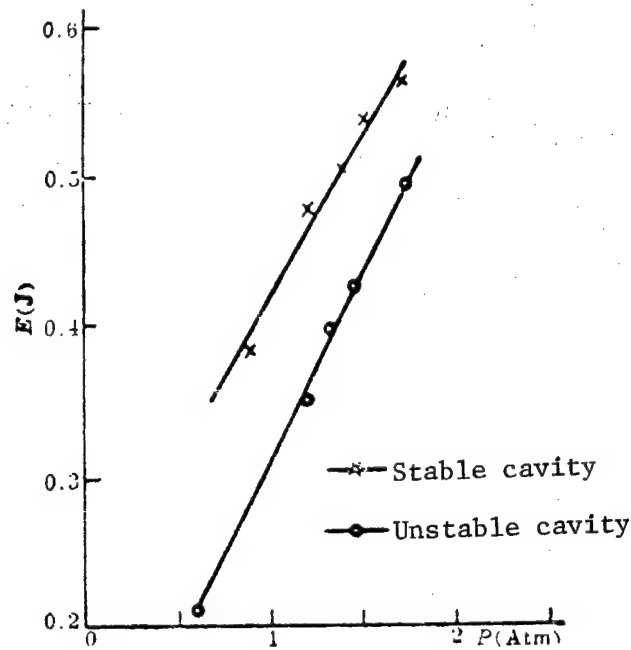


Figure 5. Laser Output Energy vs Rail Gap Switch Gas Pressure for Stable and Unstable Cavities

We used lens focusing to determine the directionality of the unstable cavity's laser output. The total overall divergence angle was only 1/4 to 1/5 that for the stable cavity, and since it contains 70-80 percent of the output energy, the divergence angle can be decreased to about 2 mrad.

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## APPLIED SCIENCES

### SINGLE-MODE $\text{Ne}^{3+}$ GLASS LASER DESCRIBED

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 7 No 7, Jul 84  
pp 585-589

[Article by Zhang Guifen [1728 6311 5358], Shanghai Institute of Optics and Precision Mechanics, CAS: "A Single-Mode Neodymium Glass Laser Resonator"]

[Text] Abstract. A high-power single-mode output has been obtained from an unstable ring laser made of neodymium glass, using an  $\text{LiF:F}_2^-$  saturable absorber crystal as a Q switch. A preliminary discussion of the experimental results is presented.

#### I. Introduction

Single-mode lasers (either longitudinal or transverse mode) have important applications in nonlinear optics and spectroscopic research. Only in single-mode operation can their high brightness, the characteristic that distinguishes them from other light sources, be thoroughly realized. The usual method for selecting the longitudinal modes is to place a Fabry-Perot etalon in the cavity or use a resonant reflector.

This method involves one major problem, namely a drastic drop in output power. In addition, it cannot be used in unstable cavities, which are effective in selecting transverse modes. This is because the characteristic mode of an unstable cavity is a spherical wave, which greatly decreases the spectral resolution of the F-P etalon [1], in addition to increasing losses. This method can be used only in small-aperture transverse mode-selecting stable cavities where the volume of the fundamental mode is extremely small, so that the output is at a very low power level. Another method for selecting longitudinal modes is to use a passive Q-switch. This method has given rather good results with solid laser materials having narrow-line fluorescence such as  $\text{YAG:Nd}^{3+}$ . Although we have also obtained a single-mode output from broad-fluorescence-band materials such as neodymium glass [2], several longitudinal modes are always present simultaneously. This is primarily because of the inversion particle spatial hole-burning effect. We therefore used an unstable ring cavity coupled with an  $\text{LiF:F}_2^-$  crystal mode selector, achieving stable single-mode output at high power.

## II. Experimental Apparatus and Ring-Instability Mode Structure

The experimental apparatus is shown in Figure 1. Mirrors  $M_1$ - $M_4$  form an unstable rectangular ring cavity;  $M_2$ - $M_4$  are  $45^\circ$  mirrors that are completely reflective at  $1.06 \mu\text{m}$ , while mirror  $M_1$  is an output coupler with a reflectivity of 50 percent. Lenses  $f_1$  ( $f_1 = 100 \text{ cm}$ ) and  $f_2$  ( $f_2 = 60 \text{ cm}$ ) form a Kepler telescope with a magnification  $f_1/f_2 = 1.66$  with a coating having high transmissivity at  $1.06 \mu\text{m}$ .  $M_5$  is a feedback mirror whose coating is completely reflective at  $1.06 \mu\text{m}$ , and is used to achieve one-directional traveling wave operation. Lenses are superior to curved mirrors for an unstable ring resonator because they do not produce astigmatism, so that the output beam quality is high [3].  $D_1$  and  $D_2$  are aperture diaphragms, with  $D_1 = 1.5 \text{ mm}$  and  $D_2 = 3.5 \text{ mm}$ . The size of  $D_2$  must be matched to the diameter of the glass rod. If the size of  $D_1$  is decreased, the directionality of the laser is improved, it also raises the lasing threshold and thus improves tuning precision. A is a neodymium glass rod  $6.3 \text{ mm}$  in diameter and  $150 \text{ mm}$  long. B is an  $\text{LiF:F}_2$  crystal Q switch, C is a calorimeter and D a photodiode; the main cavity length  $D$  is  $240 \text{ cm}$ . If focal lengths  $f_1$  and  $f_2$  are decreased while keeping  $m$  unchanged, the structure becomes more compact, and the output pulses become narrower.

As we know, an unstable ring resonator has two intrinsic modes, one clockwise, called the forward mode, and the other counterclockwise, called the backward mode. These two modes have the same gain and thus the same loss and lasing threshold. In each passage around the resonator, the dimensions of the transverse mode are increased by a factor  $m$ ; we call it the divergent wave. In Figure 2 the solid line represents the forward divergent wave, and the dotted line represents the backward divergent wave. It can be seen from Figure 2 that if two divergent waves (both characteristic modes of the cavity) propagate in opposite directions, with each passage around the cavity the size of the transverse mode will be decreased by a factor of  $m$ . We call these the convergent waves. We have already proved that the convergent wave is only a formal solution, not a real solution [4]. The reason is that the convergent wave is not resistant to perturbation. If the radius of curvature  $r$  of the intrinsic mode has an infinitesimal deviation  $\Delta r$ , in one round trip through the cavity the deviation of the divergent wave is  $\Delta r/m$ , while that for the convergent wave is  $m\Delta r$ . Therefore only a divergent wave can form in the cavity. This property of unstable cavities assures that they are resistant to perturbations and also decreases the precision requirements regarding matching of mirror  $M_5$ .

The forward mode pattern in an unstable ring resonator is simple. In order to convert a backward wave into a forward wave so as to achieve obtain a one-directional traveling wave, the design of the feedback mirror must be matched to the backward wave. Thus we must find the radius of curvature of the backward wave. Based on the condition of reproducibility and the image formula from geometrical optics, we readily find the distance  $L$  from the backward-wave center of curvature to lens  $f_1$ :

$$\left. \begin{aligned} \frac{1}{L} + \frac{1}{S'} &= \frac{1}{f_1}, \\ \frac{1}{S''} + \frac{1}{d-S'} &= \frac{1}{f_2}, \\ L &= d - d - S'', \end{aligned} \right\} \quad (1)$$

where  $\Delta = f_1 + f_2$  and  $d$  is the length of the ring cavity. Solving these equations, we obtain

$$L = \frac{m^2 d - m(m+1)\Delta}{m^2 - 1}. \quad (2)$$

From  $L$  and the position of the output coupling lens we can determine the radius of curvature and position of the feedback mirror.

### III. Experimental Results

A. Transverse mode selection uses the characteristics of an unstable cavity. A large body of experimental results attests that single transverse mode operation is readily achieved in an unstable cavity. We use the wedge method to measure the divergence of the laser output. These results prove to be essentially the same as those for the standing wave field. From the far-field spot size we calculated a divergence of  $0.6 \times 10^{-3}$  radians, 1.8 times the limiting diffraction angle.

B. To select the longitudinal mode, we used the spatial hole-burning effect resulting from depletion of inversion particles by the traveling wave field produced by the ring resonator, combined with the natural ability of a passive Q switch to select the longitudinal wave.

1. Obtaining a Traveling Wave Field. One way of obtaining a unidirectional traveling wave in an unstable ring resonator is to use aperture diaphragm  $D_1$  to increase the volume ratio of the forward and backward modes. In free lasing, diaphragm  $D_1$  increases the energy ratio of the forward and backward outputs to  $E^+/E^- \approx 6.5$ . This is smaller than the value calculated from geometrical optics, which means that diffraction at  $D_1$  produces the value deviating from that predicted by geometrical optics. A large ratio of forward to backward wave intensities was produced primarily by feedback mirror  $M_5$ . Use of a semitransparent output coupling mirror  $M_1$  not only increased the laser's far-field radiation intensity and avoided the annular output structure of most unstable cavities [3], but even more importantly, in this way we were able to effectively couple the backward wave into the forward wave, obtaining a unidirectional traveling wave. The input to the photodiode was displayed on an oscilloscope, allowing us to measure the intensities of the forward and backward waves. In free lasing without a feedback mirror, the intensities of the forward and backward waves were approximately the same. When the feedback mirror was added, the directional ratio of these two waves was  $I^+/I^- \approx 130$  and we may conclude that single-mode operation had been achieved; the pulse structure was entirely different from that of a standing-wave cavity. The pulses from standing-wave cavities generally show an irregular peak structure as in Figure 3a. But the peaks from the traveling wave field formed a regularly decaying pulse train as shown in Figure 3b. The pulse spacing was approximately uniform, entirely agreeing with what was expected from the single mode rate equation.

2. Mode Selection with an  $\text{LiF:F}_2$  Crystal Switch. Because a passive Q switch has a long pulse buildup time, it is capable of natural selection of longitudinal modes [5]. In the Q-switch state, a feedback mirror was used to obtain



a forward-backward wave intensity ratio of  $I^+/I^- \approx 110$ , which may be regarded as traveling wave operation. Combining this result with the effect of the passive Q switch, we can obtain stable-pulse single longitudinal mode output. The pulse waveform is gaussian with a fairly smooth pulse envelope, as shown in Figure 4a. The shape reproducibility of the pulses was excellent, both with pulses at 10-minute intervals and in continuous production of several dozen pulses. No pulse envelope overmodulation was observed. When two or three longitudinal waves are being generated simultaneously, beating between the modes produces serious modulation in the envelope. When the number of longitudinal modes is still greater, the modulation depth becomes smaller. Figure 4b shows the waveform for multiple longitudinal mode operation. Figures 4c and 4d are Fabry-Perot interference patterns for single and multiple modes. Because the Fabry-Perot pattern is constrained by several factors, using the smoothness of the wave envelope to judge the mode status is a simple and sensitive method [6].

The advantage of using the method described above to obtain single modes is that it does not decrease output power, giving a value very close to that for a standing-wave cavity. The results are shown in Table 1. The variations in output power are the same as for a stationary wave cavity.

#### IV. Discussion

The use of the feedback mirror method to achieve traveling wave operation relies on the ability of the mirror to convert a backward wave to a forward wave, which requires a time process. The longer the pulse buildup time, the greater the number of round trips by the wave in the cavity, and accordingly the greater the intensity ratio of the forward and backward waves. Because the forward and backward waves have the same lasing threshold, we can make the intensity of the forward wave much greater than that of the backward wave, but we cannot eliminate the backward wave altogether. Experimentally, we generally find two waves propagating at the same time, and therefore this method can only be used for long pulse buildup times. The passive Q switch meets exactly this requirement, because when the light from spontaneous noise reaches the laser threshold, the passive switch has rather large losses, and during this phase the light field intensity within the cavity increases slowly. Only when the saturated power value is reached do the losses drop sharply; the light intensity then increases rapidly, forming a giant pulse. For a noise power of  $10^7$  photons/mode to reach the threshold power (about  $10^{24}$  photons/mode) of an  $\text{LiF}_2:\text{F}_2^-$  crystal (about  $10^5 \text{ W/cm}^2$ ) requires a gain of  $10^{17}$ . If we choose  $R'G \approx 1.1$  (above the threshold value), where  $R'$  is the effective reflectivity of the output-coupling mirror and  $G$  is the single-pass gain of the medium, then it needs to make 410 circuits of the cavity. When the feedback mirror is present, the intensity ratio of the forward and backward waves in the cavity is  $I^+/I^- = R + (n-1)T^2/R'G$ , where  $T=1-R$  is the transmissivity of the output coupling mirror, and  $n$  is the number of trips around the cavity. In the experiment described above,  $R=0.5$ . Choosing  $R'G \approx 1.1$ ,  $n = 410$ , we find  $I^+/I^- = 95$ . In other words, with the Q switch not completely open, the intensity ratio of the forward and backward waves is already large. When the switch is fully open, the intensity ratio increase still further and approaches the experimentally measured value.

It is evident that increasing  $T$  helps quickly convert the backwards more into the forward mode, but this may increase the lasing threshold. To select a suitable value of  $T$  we must make allowance for various factors.

### Conclusions

Use of an  $\text{LiF:F}_2^-$  crystal as a passive Q switch in an unstable ring resonator made of neodymium glass resulted in a stable high-power single-mode output with excellent pulse reproducibility. The output energy and power variations were close to those for a standing-wave cavity. Use of an unstable ring resonator is an effective method of achieving single-mode operation.

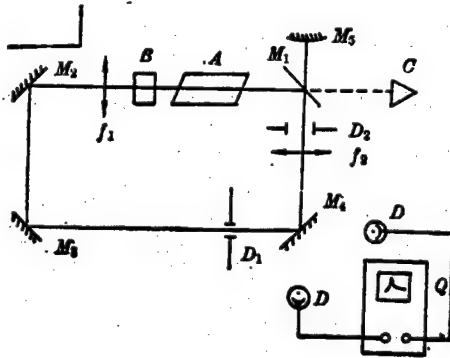


Figure 1. Experimental set-up

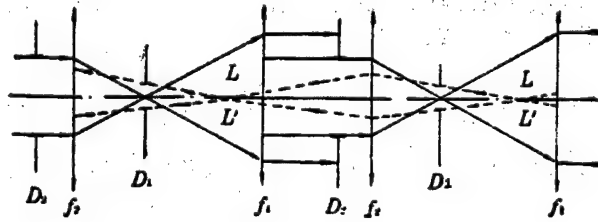
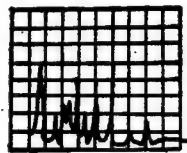
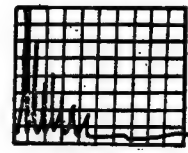


Figure 2. Modes in an unstable ring resonator



(a)

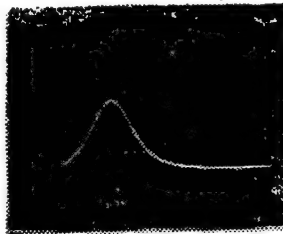


(b)

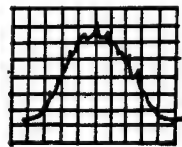
Figure 3. Pulse structures under free oscillation condition

(a) Stationary wave;

(b) Traveling wave



(a)



(b)



(c)



(d)

Figure 4. (a), (c) Pulse shape and F-P interferogram of a single mode; (b), (d) Pulse shape and F-P interferogram of a multimode

Table 1. Output Parameters

LiF:F <sub>2</sub> <sup>+</sup> (T <sub>0</sub> )	Energy	Pulse width	Output power variation	Static-dynamic ratio
T <sub>0</sub> = 65 percent	200 mJ	100 ns	± 6 percent	0.5
T <sub>0</sub> = 80 percent	100 mJ	2 μs	± 6 percent	0.42

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APPLIED SCIENCES

LASER METHOD USED TO SEPARATE URANIUM ISOTOPES

HK180943 Beijing ZHONGGUO XINWEN SHE in Chinese 1417 GMT 17 Nov 85

[Report: "China Applies Laser Method To Separate Uranium Isotopes"]

[Text] Beijing, 17 Nov (ZHONGGUO XINWEN SHE)--Our reporter learned from the Ministry of Nuclear Industry that China recently succeeded in using an internationally acknowledged technique, the laser method, to separate uranium-235, thus joining the few countries that have mastered this technology.

The experiment on the separation of uranium isotopes was conducted in the physicochemical research institute of the Ministry of Nuclear Industry by means of atomic steam laser. In the experiment, Chinese specialists used a dye laser apparatus as the light source for generating selective laser, with ultraviolet rays as the light source for ionization, to conduct one-time separation of uranium-235 and uranium-238 from natural uranium, by means of uranium atomic beams in the vacuum chamber.

For one-time separation, the laser method is an advanced uranium separation technique which is receiving more and more attention from international nuclear industrial circles. In comparison with the proliferation method and the centrifugation method, the laser method has the strong points of lower investment, lower consumption of electric energy, and savings in uranium resources. At present, only the United States, Japan, and France have mastered this technology. However, the laser method in these countries is still in the intermediary experimental stage. It is expected that only by the end of this century or in the early 21st century, can this technology be put into commercial production.

China, in the main, applies the proliferation method to nuclear fuel production, although it has mastered the centrifugation method. From 1973, Chinese specialists began to conduct a study on the laser method on the suggestion, and with the support of Wang Chengshu, a famous Chinese scientist, and professor Wu Zhengkai. In this experiment, Chinese specialists obtained technology concerning the evaporation of metal uranium and data on the uranium spectrum. An analysis proved that China's experiment produced a high separation coefficient.

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APPLIED SCIENCES

XINHUA INTERVIEWS SPACE TECHNOLOGY EXPERT

OWO91446 Beijing XINHUA in English 1431 GMT 9 Nov 85

[Text] Beijing, 9 Nov (XINHUA)--A senior Chinese expert today described the launching and retrieval of China's 17th satellite as "marking the progress of Chinese satellite technology from the experimental to the application phase."

The satellite, designed to carry out a general survey of China's natural resources, was launched on 21 October and came back to a pre-selected spot in Sichuan Province, southwest China, on 26 October.

It made 80 revolutions around the earth and took pictures while flying over China, according to Sun Jiadong, chairman of the Chinese Academy of Space Technology, in an interview with XINHUA.

It would take 6 to 8 years to complete a territorial map of China by aerial photography, Sun said, but with satellite materials the time would be "remarkably" shortened.

The satellite would help tackle a number of key problems in national economic development, Sun said. For example, it will help determine how effective are the afforestation projects already built in northern China.

Work is now underway to build a "green great wall," a tree-belt system designed to snake from the northeast to the far west, through the Loess highlands which suffers from the most serious water and soil erosion in China.

The satellite will also help determine the amount of silt carried downstream by the Yellow River and solve the problem of slowing down sedimentation at the river's estuary by the Yellow Sea.

This will facilitate the work to select sites for building new ports, Sun explained.

Sun believed that the development of space technology will also promote China's electronics, chemical, metallurgical and machine-building industry.

He expressed the hope to cooperate with other countries in developing space technology, through manufacturing and launching satellites, and provision of knowhow and ground services.

Some countries are negotiating with China on such cooperation, he said.

China plans to launch more communications, resources-survey, and meteorological satellites to serve the country's economy, said Sun.

It launched its first satellite in 1970.

/9604

CSO: 4010/12

APPLIED SCIENCES

USE OF MICROPROCESSOR FOR IMAGE PROCESSING

Beijing WEIJISUANJI YINGYONG [MICROCOMPUTER APPLICATIONS] in Chinese Vol 6 No 2,  
Mar 85 pp 47-49

[Article by Liu Weixian [0491 4850 3759], Sun Xuemei [1327 1331 5019], and  
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[Text] I. Introduction

Digital image processing is a rapidly developing field. As computers have developed, its range of applications has expanded continuously, and it is becoming increasingly established in all areas of scientific research and production.

One of the striking characteristics of image signal processing is the immense amount of data involved. In the past it was customary to associate digital image processing with large- and medium-sized computers. In recent years microcomputer technology has developed rapidly, and the capabilities and capacities of such computers have expanded rapidly, while their price has fallen continuously. The use of microcomputers to create various types of image processing systems is receiving increasingly serious consideration.

Below we describe an image processing system which we designed and installed, based on a Z-80 single-board computer.

II. System Architecture

The system consists primarily of a camera, an image signal ADC [analog-digital converter], a Z-80 single-board computer, a CRT monitor, and a timing circuit (see Figure 1).

The system has an internal memory of 96 Kbyte, of which 64 Kbyte is used to store image data (reusable memory). It is capable of storing a 256 x 256 pixel image (or four 128 x 128 pixel images); 32 Kbyte is used for system software and user program storage. The machine's conversion and processing accuracy is 8 bits (256 grayness levels).

Below we focus on several important aspects of the system design.

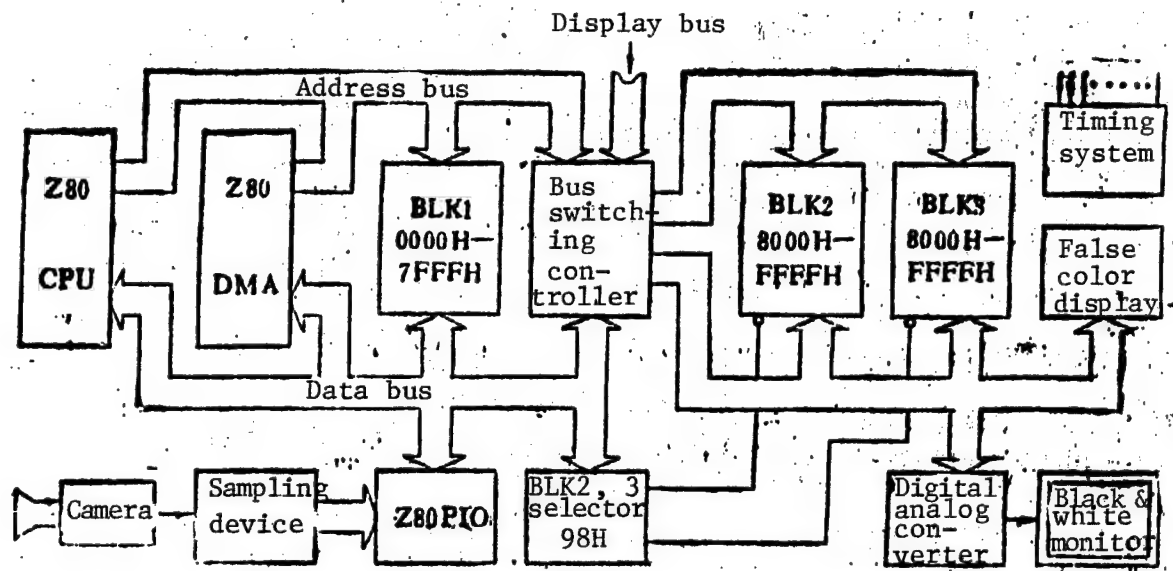


Figure 1. 256 x 256 Image Processing System

#### A. A Sampling Method Suited to Microcomputer Image Data Input

The video frequency signal is passed through an ADC to form a digital signal, which is entered into the computer via a parallel interface (Z-80 PIO) in the interrupt mode. For matching to this data transmission method we designed the following sampling device: sample one point during the line trace of the video signal and sample one column during the field trace. The sampling sequence is vertical, from top to bottom.

When the image data are input, the Z-80 PIO's interrupt mode 2 is used. The field synchronizing signal is used as the BSTB signal at port B; each time a field synchronizing signal arrives port B produces one interrupt, and during this period a port A interrupt is used to input the data. The control signal for ASTB is produced by the sampling pulse, which is delayed and shaped. The entire input process begins with execution of an input routine to start the sampling device, and after 256 sweep fields a 256 x 256 8-bit complete image is entered into the microcomputer. The time required is 5 seconds.

#### B. Implementing a High-Speed CRT Display in the Microcomputer

The Z-80 single-board computer uses 2114-series static memory with a memory cycle of between 200 and 450 ns. Use of the ordinary compilation and address selection method would not satisfy the requirements of the high-speed CRT display.

How is this problem solved? Since when displaying the image only the memory's read state is required, and since according to the handbook the 2114-series static memory read-state chip select signal takes an effective time  $t_{50}$  of 70-120 ns to reach the output, we calculate that the corresponding data readout speed can be as high as 14-8 Mc/s, which offers the possibility of implementing a high-speed CRT display.



Based on the above analysis we designed a memory matrix organization method and the corresponding read circuits. In this circuitry, when the data that have been read out are being displayed, all of the memory's read-write lines are held in the read state; their address signal changes only 1/32 as fast as the chip select signal. In other words, for each memory unit the address line and read-write line signals are in a steady state compared to the chip select line signal, so that the chip select signal can be fast. Therefore, by using this circuitry the stored data can be read out at high speed, displaying a stable image on the screen.

### C. Structure of Double-Use Memory

The use of part of the Z-80 microcomputer's main store as a CRT display buffer memory is a characteristic feature of this system.

To store a 256 x 256-element by 8-bit image requires a total of 64 Kbyte of memory capacity, and the Z-80's CPU has a maximum of 64 Kbyte of directly addressable memory. In order to unify the entire apparatus into a system that not only can store image data but also has arithmetic processing capabilities, we must use some of the internal storage for control, software and processing programs, which requires an internal storage of more than 64 Kbyte. First we make the following memory allocation: 0000H-7FFFH is used for system software and user programs and is called BLK1; 8000H to FFFFH is used to store image data and is called BLK2. In addition, we add 32 Kbyte of memory designated BLK3, which uses the same addresses as BLK2. These two blocks have a total capacity of 64 Kbyte and are used to store the upper and lower halves of a 256 x 256-pixel image.

Next, we use an I/O [input-output] port (address 98H) especially for identification control of BLK2 and BLK3. By means of the control words written into this port we switch between the two memory blocks. For example, when the program writes an 02H in this port, this means that BLK2 is being processed (the upper half of the image), while when it writes 03H this means that BLK3 is being processed (lower half of the image).

In addition to the above, in order to achieve high-speed data transmission the system also uses the DMA [direct memory access] mode. This mode can be used between the main store and internal memory (e.g. BLK1 and BLK2) or between internal memory and external devices.

### III. System Software and Program Characteristics

This system is expanded and improved from the TP801 single-board computer. In addition to the original software, we have written a variety of image processing function software, such as histogram statistics and display, image enhancement, image segmentation, filters of various types, edge detection, isolated object search and the like. Some of the constantly used functional software has already been placed in EPROM [erasable programmable read-only memory]. For conveniences of use, we have also expanded and modified the supervisor program so that the permanent image processing programs can be executed by pressing a single key.

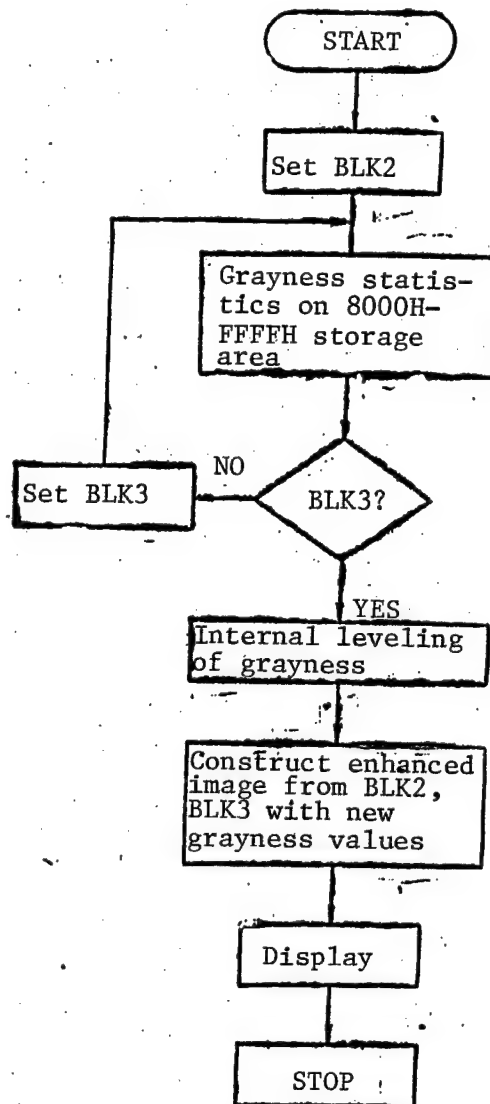


Figure 2. Histogram-Leveling Enhancement Processing Flowchart

In the system's double-use memory the pixel data are stored sequentially, and every pixel's storage address and its geometrical position within the image are in a specified relationship. When a register is used for addressing, the high-order byte corresponds to the line number of the pixel, while the low-order byte corresponds to its column number. This feature greatly increases convenience in writing processing software.

When writing the processing programs, it must be borne in mind that the image is stored as top and bottom halves. To illustrate programming in this system, Figure 2 shows the flowchart for a program which performs image enhancement by the histogram leveling method.

When this system is used, as soon as the image data are input, the entire data matrix is in the CPU's addressable memory area, so that the execution of the

processing program is extremely fast. For example, for a 256 x 256-element image, only about 10 seconds is required for histogram-leveling image enhancement. A single filtering and smoothing operation on an image of the same size would require about 30 seconds.

#### IV. Conclusions

We have already used this system in a variety of image processing experiments. In addition to observing the processing results on a black-and-white or color monitor, it is also possible to record the image on a facsimile machine. Because of difficulties with printing, no picture processing results are published with this article.

Experience has shown that this system is indeed a flexible, reliable, fast, cheap, and versatile microcomputer image processing device. It is particularly well suited to certain specialized fields (such as biological and medical image processing and the like) and to use as a teaching and experimental device for courses in digital image processing. This will have positive effects on image processing technology research and development.

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APPLIED SCIENCES

MICROCOMPUTER FAST FOURIER TRANSFORM SYSTEM DESCRIBED

Beijing WEIJISUANJI YINGYONG [MICROCOMPUTER APPLICATIONS] in Chinese Vol 6  
No 2, Mar 85 pp 18-24

[Article by Jiang Yinlin [5592 6892 2651], Institute of Acoustics, CAS: "An FFT Analysis System for the DPS-85"]

[Text] The DPS-85 data collection and analysis system (produced by the digital systems development department of the Institute of Acoustics) includes a rather powerful FFT (fast Fourier transform) processing capability which is lacking in ordinary microcomputer systems. As a result, it can be used not only as an ordinary microcomputer, but also as a simple FFT signal analyzer which is extremely well adapted for low-frequency signal processing.

I. Function of the FFT in Signal Analysis

As we know, the Fourier transform, an extremely useful mathematical analysis technique, is defined as follows:

$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-j2\pi ft} dt \quad (1)$$

where  $x(t)$  is the time-domain formula and  $X(f)$ , the frequency domain formula, is the Fourier transformation of  $x(t)$ . For digital calculation of a Fourier transform on a computer, the integral form of the continuous signal must be expressed as a sum of discrete signals (the discrete Fourier transform, DFT):

$$X(K) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j2\pi nK/N} \quad K = 0, 1, \dots, N-1 \quad (2)$$

Direct calculation of the DFT requires  $N^2$  complex multiplications and  $N(N-1)$  complex additions, which is an excessive amount of computation. The FFT is a rapid algorithm for calculating the DFT which decreases the amount of calculation needed for the DFT from  $N^2$  to  $\frac{N}{2} \log_2 N$  calculations, so that the FFT algorithm becomes a very basic algorithm for digital signal processing.

The FFT can be used for most ordinary signal processing. The FFT computation result is given in the form of its real and imaginary part, and it is easy to obtain the amplitude spectrum  $|X(K)|$ , the phase spectrum  $Q(K)$  and the power spectrum  $P(K)$ :

$$|X(K)| = \sqrt{R^2(K) + I^2(K)} \quad (3)$$

$$Q(K) = \tan^{-1} I(K)/R(K) \quad (4)$$

$$P(K) = |X(K)|^2 = R^2(K) + I^2(K) \quad (5)$$

By the convolution theorem, if the Fourier transformations of time signals  $h(t)$  and  $x(t)$  are  $H(f)$  and  $X(f)$ , then the Fourier transformation of the convolution of  $h(t)$  and  $x(t)$  is  $H(f) \cdot X(f)$ , which we write as follows:

$$h(t) * x(t) \Leftrightarrow H(f) \cdot X(f) \quad (6)$$

Similarly, we have the correlation theorem

$$\int_{-\infty}^{\infty} h(\tau) \cdot x(t+\tau) d\tau \Leftrightarrow H(f) \cdot X^*(f) \quad (7)$$

Thus we can use the FFT algorithm to perform convolution and correlation calculations. We first perform the FFT calculation on the time-domain signals, obtaining their Fourier transformations, then multiply them in the frequency domain (a conjugate multiplication in the case of the correlation), then use the IFFT (inverse fast Fourier transform) to obtain the convolution or correlation. Extending the method further, we can calculate transfer functions, coherence functions and the like. Clearly the FFT is extremely important in signal analysis.

## II. Use of a Microcomputer To Calculate the FFT

Microcomputer applications are expanding rapidly, particularly in the case of 8-bit microcomputers. Technical personnel dealing with signal analysis naturally wish to use microcomputers for FFT calculations. As a digital algorithm, the FFT can be performed by any computer, but time and speed are a problem. Ordinarily an 8-bit microcomputer requires from 10 minutes to many tens of minutes to calculate a 1024-point FFT using a program written in BASIC. An FFT program written in assembly language will be much more efficient, requiring from 10 seconds to several tens of seconds. In the case of the Japanese TEAC Company's PS-80, for example, the statistical analysis software can calculate a 512-complex-point FFT in 45 seconds (or 20 seconds in the case of the PS-85, with a 4 MHz clock). This processing speed is still quite inadequate for real signal analysis. Accordingly, in order to have 8-bit microcomputers play an effective role in signal analysis, the key is to increase the processing speed further. The DPS-85 is an effort in this direction: by the use of a fast ALU [arithmetic and logic unit] and optimal program design, it decreases the time required for a 512-complex-point FFT to about 0.5 seconds, so that it can cope effectively with signal analysis.

## III. The Fast ALU

Use of an FFT program written in assembly language reveals that most of the time is spent in multiplication operations. It takes an 8-bit microprocessor

several microseconds to perform a 16-bit add operation, but a 16 x 16 bit multiplication requires several hundred microseconds. Therefore the key to increasing FFT processing speed is to decrease the multiplication load on the central processor. Therefore, we designed a fast ALU whose nucleus is a fast multiplier; it is diagrammed in Figure 1. It consists of a multiplier, an instruction register, buffer registers, a multiplexer, a data bus driver, an address decoder, and control circuitry. The fast ALU is designed to act as the CPU's I/O [input-output] port.

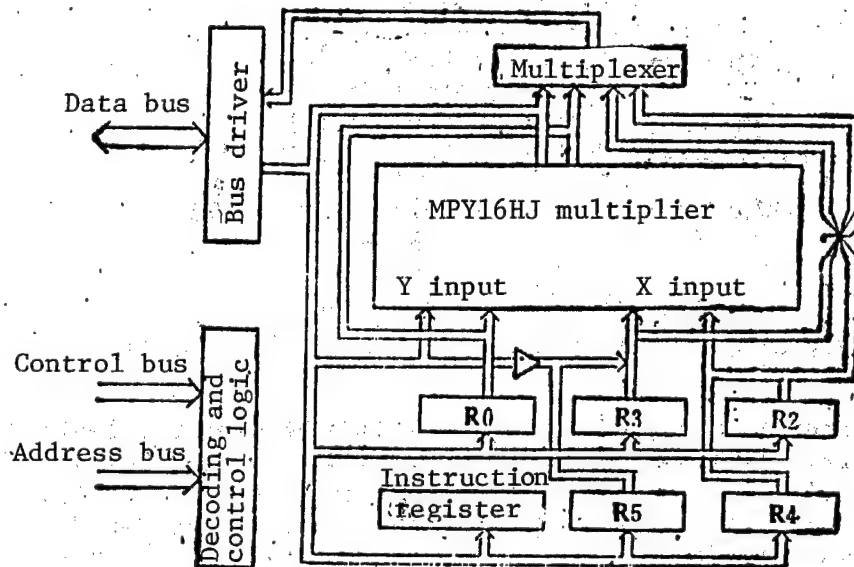


Figure 1. Block Diagram of Fast ALU

The multiplier uses a MPY16HJ 16 x 16 bit parallel multiplier with a 32-bit double-precision output, produced by TRW (United States). It can perform two's complement, unsigned integer, and mixed-mode multiplication. Its logic diagram is shown in Figure 2. It consists of an input latch, a multiplication logic array, an output format adjust unit, an output latch, and an output buffer. The X and Y input latches are both 16 bits long and are used to store the multiplier and multiplicand. The signals TCX and TCY express the input data format: if they are high (logical 1), they indicate a two's complement number, while if low (logical 0), they indicate an unsigned integer. RND, the roundoff control signal, determines whether rounding off is performed when a single-word-length product output is obtained. All latches are positive-edge triggered flip-flops. The FT [feed through] input is used to make the multiplication bypass the output latch, so that it is sent out directly. The product output is 32 bits: MSP is the high-order 16 bits and LSP the low-order 16 bits. Note that because of the limited number of pins on the package, the LSP output and Y input share common pins and must be used in the time-sharing mode. The RS signal controls the output data format: when it is low, the high-order bits of MSP and LSP are sign bits; when it is high, MSP is shifted rightward one bit and the sign bit of LSP is discarded.

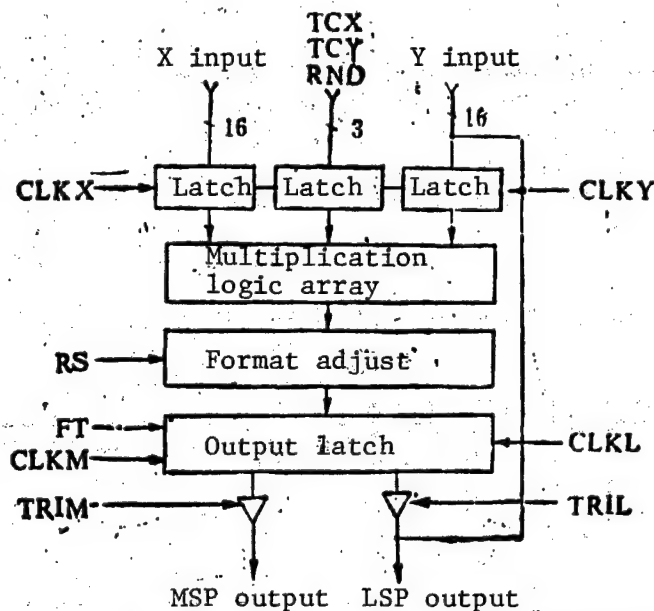


Figure 2. Logic Diagram of MPY16HJ Multiplier

The buffer register is designed to exchange data between the 8-bit CPU and the 16-bit multiplier. As shown in Figure 1, in order to transfer a 16-bit number to the multiplier's Y latch, it is first necessary to send the lower 8 bits to buffer R0, then to transfer the higher 8 bits to the high-order 8 bit input of Y, after which the rising edge of the CLKY pulse loads the higher and lower order 8 bits simultaneously into the Y latch. Similarly, to transfer 16 bits of data to the X latch, first the low-order 8 bits are transferred to R2, after which the high-order 8 bits are transferred via a tri-state gate to the high-order 8-bit input of X, and the rising edge of CLKX simultaneously loads the 16 bits of data into latch X. Buffer registers R3, R4, and R5 are designed for complex multiplication, as will be described below. These buffer registers are all 8-bit registers (74LS374) with tri-state output.

The instruction register is an 8-bit register which stores instructions from the CPU and controls the mode of operation of the fast operation unit. The instruction format is shown in Figure 3.

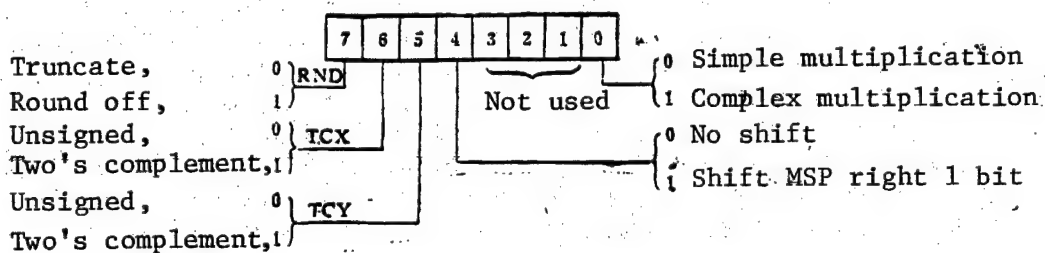


Figure 3. Instruction Format of Fast ALU

Bits 4-7 of the instruction register directly control the multiplier unit and need no further description. Bit 0 controls the type of multiplication: "0" causes simple multiplication, in which the multiplicand A and multiplier B are transferred to latches X and Y, after which the product is obtained at the output. A "1" produces complex multiplication, which is particularly well suited to the type of multiplication in which an array D is multiplied by two constants A and B, i.e.  $P(I) = D(I) \cdot A$ ,  $Q(I) = D(I) \cdot B$ . In this case A and B are preloaded into R2-R3 and R4-R5, and one number D(I) (where I is the sequential number of the data) is transferred to input latch Y, so that P(I) and Q(I) can be successively obtained at the output. This avoids repeated transfer of multipliers between the CPU and the multiplier unit and saves time. This feature is very useful in FFT operations.

The multiplier output passes through the multiplexer to the system data bus. The multiplier unit's MSP and LSP outputs are tri-state buffers. We tied the two together: time-shared transfer from MSP and LSP is controlled by the TRIM and TRIL signals, and the 16-bit MSP or LSP is switched by the multiplexer and sent to the CPU 8 bits at a time. The multiplexer used is a 74LS153 dual 1-of-4 decoder. Two inputs are used to gate the high-order and low-order 8 bits, while the other two inputs are used to form a binary reversing circuit. In FFT computation, the initial order is sequential, so that the output is in reversed binary sequence, and accordingly the order of the resultant data must be reversed. This is the purpose of the reversing circuit. The address to be reversed is sent to R4 and R5, and the multiplexer output is the reversed address.

The data buffer is used to connect the CPU's data bus to the fast ALU's data bus; it makes use of two 8216 duplex bus drivers.

All components in the fast ALU are designed to function as I/O devices for the CPU; the address decoding logic decodes each port address, while a small amount of control logic is used for sequence control.

In DPS-85, this fast ALU is a selection plugboard that holds one LSI multiplier chip and 30 MSI and SSI chips.

#### IV. Choice of Algorithm

There are many algorithmic realizations of the FFT, which are classified as base 2, base 4, base 8, and mixed-base types, in addition to which they are classified according to the decimation method as "decimation in time" (DIT) and "decimation in frequency" (DIF). For an 8-bit CPU with relatively few registers, we selected the relatively simple base-2 DIT algorithm. Figure 4 is a signal flow diagram for this algorithm. The first sequence  $x_0(n)$  is the time sequence and is in natural order.  $x_1(n)$  and  $x_2(n)$  are intermediate results.  $x_3(n)$  is the Fourier transformation of the input sequence. But it is not in natural order by frequency and accordingly it must undergo a binary inversion in order to be turned into  $x_k$  in natural frequency order.



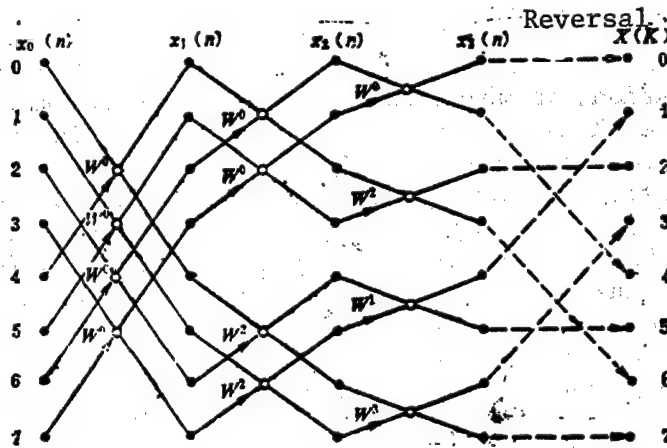


Figure 4. Signal Flow for Binary Decimation-in-time FFT,  $N = 8$

The FFT algorithm is iterative and the iteration result is represented as the following butterfly operation:

$$\begin{aligned} x'_J &= x_J + x_K \cdot W^P \\ x'_K &= x_J - x_K \cdot W^P \end{aligned} \quad (8)$$

where  $W = e^{-j2\pi/N}$ ,  $P = nK$ . In equation (8),  $x_J$  and  $x_K$  are complex numbers which are converted into real form as follows:

$$\begin{aligned} R'_J &= R_J + [R_K \cos(2\pi nK/N) + I_K \sin(2\pi nK/N)] \\ I'_J &= I_J + [I_K \cos(2\pi nK/N) - R_K \sin(2\pi nK/N)] \\ R'_K &= R_J - [R_K \cos(2\pi nK/N) + I_K \sin(2\pi nK/N)] \\ I'_K &= I_J - [I_K \cos(2\pi nK/N) - R_K \sin(2\pi nK/N)] \end{aligned} \quad (9)$$

Each butterfly includes four real multiplications and six real additions.

In the FFT algorithm the initial data are defined by complex numbers, but the signals actually processed are all real signals. Accordingly we can select an algorithm suited to the actual signal to be processed. We selected the ODFT (odd discrete Fourier transform) algorithm, defined as

$$D(K) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi n(K+1/2)/N} \quad (10)$$

Compared to the DFT of equation (2), the ODFT spectral lines are shifted along the frequency axis by half the frequency sampling interval. This algorithm first takes an  $n$ -point real number sequence and divides it into two halves, performing a "normalization" operation.

$$U(n) = [x(n) + jx(n + \frac{N}{2})] e^{-j\pi n/N} \quad (11)$$

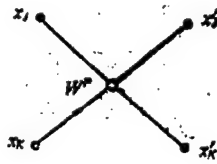


Figure 5. Diagram of Butterfly Operation

thus forming a new  $\frac{N}{2}$  - point complex function  $U(n)$ . It then simply performs the FFT on  $U(n)$  and performs an odd transformation on the result,

$$D(K) = D^*(N-1-K) \quad (12)$$

The details of the derivation are given in Reference 2.

#### V. Signal Processing Program

In order to maximize efficiency, the signal processing program in the DPS-85 equipped with the fast ALU was written in assembly language and included system management, arithmetic calculations, and input-output routines totaling 3,000 lines of code. The assembled object program, trigonometric functions, and the operational data buffer area occupy about 14 Kbyte of internal storage. There are two main programs, FFT85A/CIM and BFT85A/CIM, intended for two different methods. The first is designed for the signal analyzer mode, while the latter is designed for use with BASIC programs calling assembly-language routines. The signal analyzer mode is an extremely simple form of operation which does not require that the user have any programming knowledge. The user simply carries out the procedures specified in the instructions (pressing several relevant keys), just as in using an ordinary FFT signal analyzer. The operation flow is shown in Figure 6. Under DOS [disk operating system] control, the LOAD command causes FFT85A/CIM to be loaded, after which execution of the BASIC program begins, and once memory protection is set (to protect the highest 32 Kbyte of memory), BASFFT/BAS is executed. This program calls assembly-language routines and begins to select functions and parameters. This selection process is performed by man-machine dialog on a fluorescent screen and includes processing functions, number of sample points, sampling frequency, Hanning window weighting, number of averages, and output format. Once the selection is made, data collection begins, after which processing is performed according to the chosen mode. After the processing is completed, a plot of the results is immediately shown on a high-resolution display. The display mode is flexible; it is possible to display the real and imaginary part, the original input signal or the processing results, and they may be magnified or compressed. If it is desired to record the results, the processor returns to the BASIC program and the results are output on either a graph platter or printer.

Another mode is for the user to design his own main program in BASIC and call assembly-language signal processing routines. This offers flexibility to the user. In this mode, the user can design a BASIC program in order to supplement preprocessing and postprocessing capabilities, and all BASIC operations

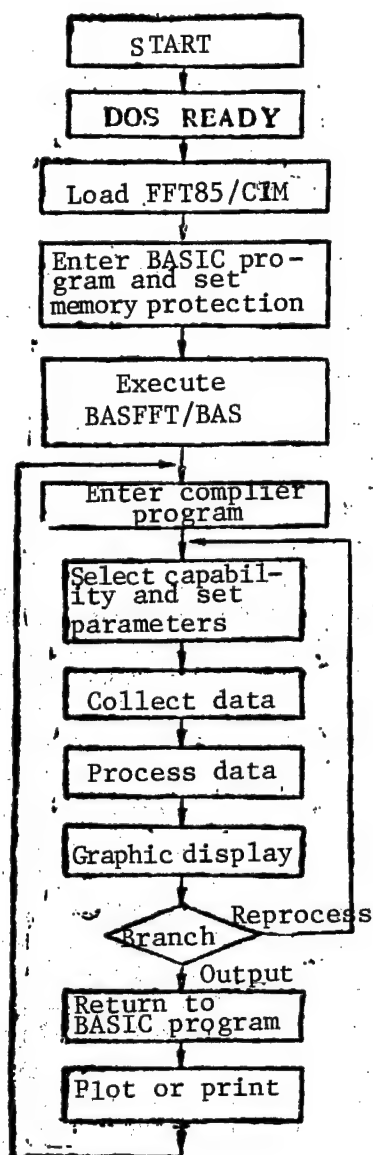


Figure 6. Flow Chart for Analyzer Mode

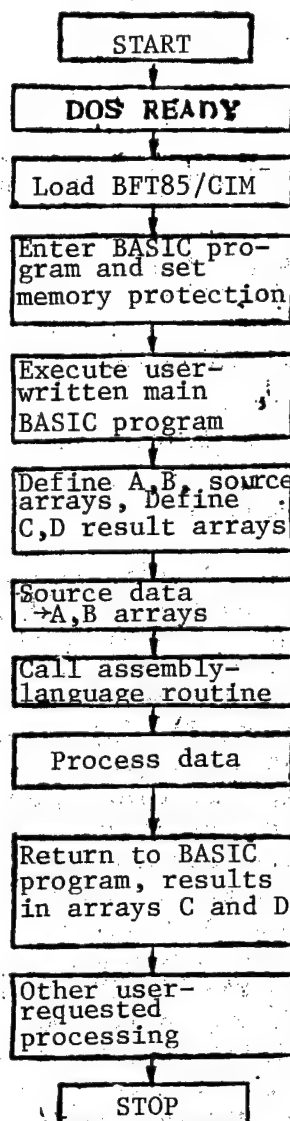


Figure 7. BASIC Program With Use of Assembly-Language Routines

involving the FFT can be carried out by calling subroutines. The flow chart for this method is shown in Figure 7. Under DOS supervision, BFT85/CIM is loaded, after which execution of the BASIC program begins. After memory protection is set, the user-designed main BASIC program is executed. This program should define the initial data arrays (arrays A or B) and result arrays (C and D), then call the relevant processing routines. When processing is complete it returns to the main program in BASIC, with the results stored in array C and D. The result arrays can be subjected to further processing.

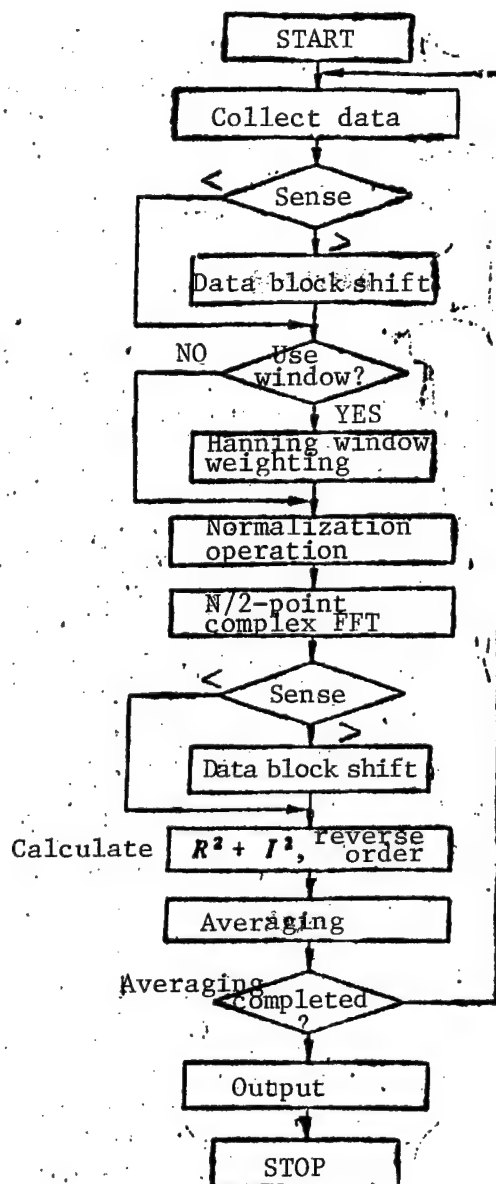


Figure 8. Flowchart for Power Spectrum Calculation

In the assembly language program, the choice of different capabilities involves different computation flowcharts. Here we use the power spectrum computation program as an example (see flowchart, Figure 8). First the data are collected and entered for testing. When a datum is above a preset threshold, in order to prevent a fixed-point computation overflow the data should be block-shifted rightward. In all other cases the data are entered directly into the computation program. If the Hanning window has been selected, then the weighting operation is first performed; otherwise the normalization operation is performed immediately. The normalization operation involves converting  $N$  points of real data into  $N/2$  complex numbers; the FFT is performed on these  $N/2$  complex

numbers. The FFT results have their real and imaginary parts output separately, and the squares of the real and imaginary parts are added to give the power spectrum. At the same time that the power spectrum is calculated, the reversing operation is performed, followed by averaging using the arithmetic mean. If the averaging is not completed, then the program returns and processes the next data array. If the averaging is completed, then the result is output (graphic display, printing, or plotting).

## 6. Capabilities

Because DPS-85 has a high-precision A/D [analog-digital] converter, a fast ALU, a high-resolution screen and a high-efficiency assembly language signal processing program, it has rather good characteristics and its range of signal processing capabilities is rather full, including the following:

1. The ADC has a word length of 12 bits and any of 10 sampling frequencies between 10 Hz and 10 kHz can be selected; the system analysis signal frequency is 0-5 kHz.
2. Signal processing features include: FFT, IFFT, self-power spectrum, cross power spectrum, autocorrelation, cross-correlation, and convolution. It is easy to expand these features further.
3. The number of samples can be 64, 128, 256, 512, or 1,024.
4. There is a Hanning window weighting feature to suppress energy leakage resulting from signal truncation.
5. There is an averaging capability: the number of averages can be 1, 2, 4, 8, 16, 32, 64, or 128.
6. There is a logarithmic conversion capability.
7. The high-resolution screen image density is 640 x 400 pixels.

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APPLIED SCIENCES

## FIELD DISTRIBUTION IN A BENT SINGLE-MODE OPTICAL FIBER

Tianjin TIANJIN DAXUE XUEBAO [JOURNAL OF TIANJIN UNIVERSITY] in Chinese No 4,  
Dec 84 pp 97-102

[Article by Bao Zhenwu [7637 2182 2976], Department of Electronic Engineering;  
Manuscript received 23 April 1984]

[Text] Abstract: An approximate equation for the field distribution of a bent single-mode fiber is presented. Measurements of the field distribution using the near-field pattern (NFP) method gave results in agreement with theoretical predictions.

### 1. Introduction

In recent years transmission losses in optical fibers have decreased considerably and low-loss fibers with values close to the limiting figure of 0.2 dB/km have been obtained. But in the manufacture of optical fibers and the production of cables from them, such nonideal factors as variations in the fiber diameter and microscopic bends produce additional losses, which must be taken into consideration for low-loss fibers. Here we discuss only the effect produced by bending of the fibers. Bending of the fiber axis will produce changes in the electromagnetic field distribution. Because the bending is random, it is very difficult to analyze variable curvature, but if in our analysis we assume bending with a constant radius of curvature the analysis becomes much simpler. D. Marcuse [1] and Kawakami [2] have made detailed studies of the field distributions in bent fibers. Below, using the theory proposed by Kawakami et al., we derive an approximate equation for the field distribution measurements made by the near field pattern (NFP) method. The experimental results indicate that the Kawakami theory is the more correct of the two. Finally, we also examine the Marcuse theory to determine where his calculation results differ from the experimental results.

### 2. Equation for the Field Distribution in a Bent Fiber

Figure 1 shows the system of coordinates for a bent fiber with radius  $T$  and radius of curvature  $R$ . We can use the perturbation method to determine the field intensity at an arbitrary point on the cross section of the bent fiber (in the XY plane):

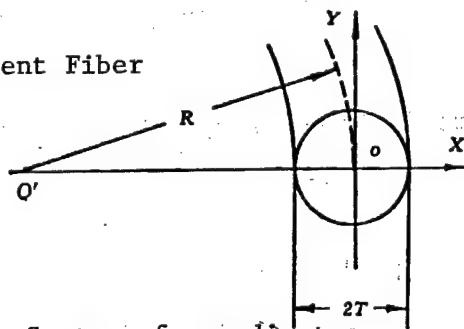


Figure 1. System of coordinates

$$E = E_0 + \frac{f}{R} \quad (1)$$

where  $E_0$  is the field intensity at an arbitrary point on the cross section of an ideally straight fiber, i.e.

$$E_0 = \begin{cases} J_n \left( u \frac{r}{T} \right) & (r \leq T) \\ \frac{J_n(u)}{K_n(w)} K_n \left( w \frac{r}{T} \right) & (r \geq T) \end{cases} \quad (2)$$

$$r = \sqrt{x^2 + y^2}$$

( $u$  is the normalized phase constant in the core and  $w$  is the normalized attenuation constant in the cladding.) In equation (1),  $f/R$  is the perturbation term, which expresses the change in the field intensity produced by bending. Under ordinary conditions,

$$f = \beta_0^2 \left\{ A_+(r) \cos[(n+1)Q + Q_0] + A_-(r) \cos[(n-1)Q + Q_0] \right\} \quad (3)$$

$$A_+(r) = \begin{cases} C_1 J_{n+1} \left( u \frac{r}{T} \right) + \frac{T}{4u} r^2 J_{n-1} \left( u \frac{r}{T} \right) & (r \leq T) \\ C_2 K_{n+1} \left( w \frac{r}{T} \right) + \frac{T}{4w} \frac{J_n(u)}{K_n(w)} r^2 K_{n-1} \left( w \frac{r}{T} \right) & (r \geq T) \end{cases} \quad (4)$$

$$A_-(r) = \begin{cases} C_3 J_{n-1} \left( u \frac{r}{T} \right) - \frac{T}{4u} r^2 J_{n+1} \left( u \frac{r}{T} \right) & (r \leq T) \\ C_4 K_{n-1} \left( w \frac{r}{T} \right) + \frac{T}{4w} \frac{J_n(u)}{K_n(w)} r^2 K_{n+1} \left( w \frac{r}{T} \right) & (r \geq T) \end{cases} \quad (5)$$

$$\left. \begin{aligned} C_1 &= -\frac{T^3}{4u} \frac{J_{n-1}(u) K_{n+2}(w)}{J_{n+1}(u) K_n(w)} \\ C_2 &= \frac{T^3}{4w} \frac{J_{n+2}(u) K_{n-1}(w)}{K_n(w) K_{n+1}(w)} \\ C_3 &= \frac{T^3}{4u} \frac{J_{n+1}(u) K_{n-2}(w)}{J_{n-1}(u) K_n(w)} \\ C_4 &= \frac{T^3}{4w} \frac{J_{n-2}(u) K_{n+1}(w)}{K_n(w) K_{n-1}(w)} \end{aligned} \right\} \quad (6)$$

where  $\beta_0$  is the propagation constant for a straight fiber.

For the fundamental LP<sub>01</sub> mode in the fiber, equations (2)-(6) can be rewritten as

$$E_0 = \begin{cases} J_0\left(u \frac{r}{T}\right) & (r \leq T) \\ \frac{J_0(u)}{K_0(w)} K_0\left(w \frac{r}{T}\right) & (r \geq T) \end{cases} \quad (7)$$

$$f = \beta_0^2 \left\{ A_+(r) \cos(Q + Q_0) + A_-(r) \cos(-Q + Q_0) \right\} \quad (8)$$

$$A_+(r) = \begin{cases} J_1\left(u \frac{r}{T}\right) \left(C_1 - \frac{T}{4u} r^2\right) & (r \leq T) \\ K_1\left(w \frac{r}{T}\right) \left(C_2 + \frac{T}{4w} \frac{J_0(u)}{K_0(w)} r^2\right) & (r \geq T) \end{cases} \quad (9)$$

$$A_-(r) = \begin{cases} -J_1\left(u \frac{r}{T}\right) \left(C_3 + \frac{T}{4u} r^2\right) & (r \leq T) \\ K_1\left(w \frac{r}{T}\right) \left(C_4 + \frac{T}{4w} \frac{J_0(u)}{K_0(w)} r^2\right) & (r \geq T) \end{cases} \quad (10)$$

$$\left. \begin{aligned} C_1 &= \frac{T^3}{4u} \frac{K_2(w)}{K_0(w)} \\ C_2 &= \frac{T^3}{4w} \frac{J_2(u)}{K_0(w)} \\ C_3 &= -\frac{T^3}{4u} \frac{K_2(w)}{K_0(w)} \\ C_4 &= \frac{T^3}{4w} \frac{J_2(u)}{K_0(w)} \end{aligned} \right\} \quad (11)$$

Substituting equations (9)-(11) into equation (8) and setting  $Q = 0$  and  $r = |x|$ , we obtain

$$f = \begin{cases} \frac{\beta_0^2 T^3}{2u} J_1\left(u \frac{|x|}{T}\right) \left[ \frac{K_2(w)}{K_0(w)} - \left(\frac{x}{T}\right)^2 \right] \cos Q_0 & (|x| \leq T) \\ \frac{\beta_0^2 T^3}{2w} K_1\left(w \frac{|x|}{T}\right) \left[ \frac{J_2(u)}{K_0(w)} + \frac{J_0(u)}{K_0(w)} \left(\frac{x}{T}\right)^2 \right] \cos Q_0 & (|x| \geq T) \end{cases} \quad (12)$$

where  $\cos Q_0$  can be chosen as follows:

$$Q_0 = 0, \cos Q_0 = 1 \text{ when } x > 0; Q_0 = \pi, \cos Q_0 = -1 \text{ when } x < 0.$$

Thus we can assume  $\cos Q_0 = \frac{|x|}{x}$  and substitute it into equation (12), obtaining



$$f = \begin{cases} \frac{|x|}{x} \frac{\beta_0^2 T^3}{2u} J_1 \left( u \frac{|x|}{T} \right) \left[ \frac{K_2(w)}{K_0(w)} - \left( \frac{x}{T} \right)^2 \right] & (|x| \leq T) \\ \frac{|x|}{x} \frac{\beta_0^2 T^3}{2w} K_1 \left( w \frac{|x|}{T} \right) \left[ \frac{J_2(u)}{K_0(w)} + \frac{J_0(u)}{K_0(w)} \left( \frac{x}{T} \right)^2 \right] & (|x| \geq T) \end{cases} \quad (13)$$

Substituting equations (7) and (13) into equation (1), we obtain the equation giving the field distribution for LP<sub>01</sub>:

$$E = \begin{cases} J_0 \left( u \frac{x}{T} \right) + \frac{|x|}{x} \frac{\beta_0^2 T^3}{2u} J_1 \left( u \frac{|x|}{T} \right) \left[ \frac{K_2(w)}{K_0(w)} - \left( \frac{x}{T} \right)^2 \right] \frac{T}{R} & (|x| \leq T) \\ \frac{J_0(u)}{K_0(w)} K_0 \left( w \frac{|x|}{T} \right) + \frac{|x|}{x} \frac{\beta_0^2 T^3}{2w} K_1 \left( w \frac{|x|}{T} \right) \left[ \frac{J_2(u)}{K_0(w)} + \frac{J_0(u)}{K_0(w)} \left( \frac{x}{T} \right)^2 \right] \frac{T}{R} & (|x| \geq T) \end{cases} \quad (14)$$

In addition, because bending will produce a stress effect which will also change the fiber's refractive index (the refractive index will increase on the inner side of the bend and decrease on the outer side), the field distribution will be affected by the stress and the perturbation will be multiplied by the factor  $(1 + \frac{ce}{n_0})$  [3]. Accordingly we can obtain the field distribution over the cross section of a bent single-mode fiber that allows for the stress effect:

$$E_s = \begin{cases} J_0 \left( u \frac{|x|}{T} \right) + \frac{|x|}{x} \frac{\beta_0^2 T^2}{2u} J_1 \left( u \frac{|x|}{T} \right) \left[ \frac{K_2(w)}{K_0(w)} - \left( \frac{x}{T} \right)^2 \right] \frac{T}{R} \left( 1 + \frac{ce}{n_0} \right) & (|x| \leq T) \\ \frac{J_0(u)}{K_0(w)} K_0 \left( w \frac{|x|}{T} \right) + \frac{|x|}{x} \frac{\beta_0^2 T^2}{2w} K_1 \left( w \frac{|x|}{T} \right) \left[ \frac{J_2(u)}{K_0(w)} + \frac{J_0(u)}{K_0(w)} \left( \frac{x}{T} \right)^2 \right] \frac{T}{R} \left( 1 + \frac{ce}{n_0} \right) & (|x| \geq T) \end{cases} \quad (15)$$

where  $e$  is Young's modulus,  $c$  is the optical stress conversion factor, and  $n_0$  is the refractive index in the core of a straight fiber. In computations we can use  $1 + \frac{ce}{n_0} = 0.8$  [3].

### 3. Measurement System and Measuring Technique

We measured the field distribution in a bent fiber by the near-field pattern (NFP) method. The fiber used was a single-mode stepped-index fiber with the following structural characteristics:  $2T$  for core =  $4.8 \mu\text{m}$ , relative refrac-

tive index variation  $\Delta = 0.20$  percent, giving a normalized frequency  $V = 2.26$  (for  $\lambda = 0.6328 \mu\text{m}$ ). We made measurements on several samples of bent single-mode fiber for radii of curvature  $R$  between 2 and 7 mm. The sample shape is shown in Figure 2. The measurement system consisted of a light source, the fiber under test, a microscope, and an X-Y plotter, as Shown in Figure 3. An He-Ne laser with  $\lambda = 0.6328 \mu\text{m}$  was used as a light source and the beam emitted from it was focused by a 40X lens onto the entrance of the fiber under test. The output end of the fiber was bent through  $90^\circ$  in a circular arc with a radius of  $R$  and the field distribution on the end surface was magnified with a microscope (40X, 50X) and directed toward a photodetector about 40 cm away.

Figure 2. Bent fiber specimen.

Key:

- a. Optical fiber
- b. Semicircular base
- c. Base

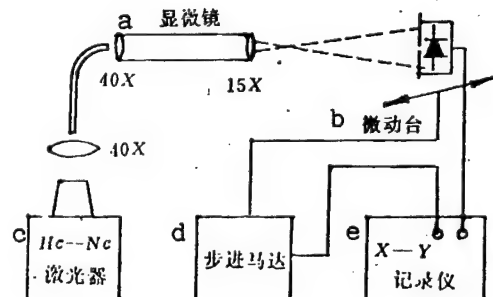
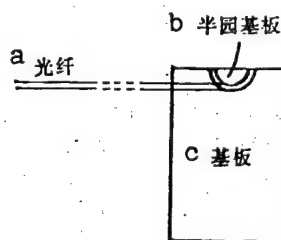


Figure 3. Measurement system.

Key:

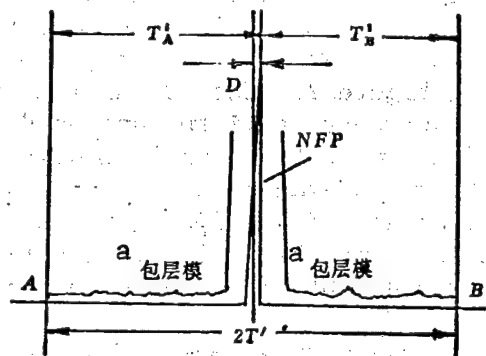
- a. Microscope
- b. Microstepping table
- c. He-Ne laser
- d. Stepping motor
- e. X-Y plotter

A mask with a radius of  $200 \mu\text{m}$  was located in front of the photodetector and integral with it; the detector was scanned horizontally with a stepping motor to detect the electromagnetic field distribution on the end surface of the fiber. The field distribution was plotted with an X-Y plotter. We also determined the deviation of the field distribution, which we described with two parameters: the field deviation from the fiber axis in the radial direction  $D$ , and the 3-dB width  $W$  of the field distribution. The field deviation  $D$  should receive particular attention. Because the field distribution is deviated by bending the fiber, the position of the field maximum should be moved outward along the radius of curvature so that it no longer coincides with the fiber axis. If the position of the axial line and the position of the field maximum can be determined accurately, the deviation  $D$  can be found. But there is no known technique for accurately determining the position of the axial line in a fine, bent fiber, so that it is extremely difficult to measure  $D$ . We therefore used a different method of determining  $D$ , as shown in Figure 4. The measurement was made in two parts. We first determined the faint field distribution in the cladding, which we called the "cladding mode." Because the cladding mode suddenly vanishes at the cladding boundaries, the positions  $T'_A$  and  $T'_B$  of the boundaries can be determined precisely and used as reference points for determining the deviation  $D$ . The second method determined the distances  $T'_A$  and  $T'_B$  from the maximum value of the transmitted

Figure 4. Determination of D

Key:

a. Cladding mode



mode near-field pattern to cladding boundaries A and B. If we assume that the position of the maximum is shifted in the B direction in which the radius of curvature increases, then the deviation can be calculated from the equation

$$D = \frac{T'_A - T'_B}{T'_A + T'_B} T' \approx \frac{1}{2} (T'_A - T'_B) \quad (16)$$

where  $T'$  is the radius of the cladding.

#### 4. Results and Analysis

Figure 5a is a two-dimensional representation of the measured field distribution and Figure 5b is an equal-intensity plot of the field distribution; the radius of curvature of the fiber under test was  $R = 4.5$  mm. Figure 6 shows the measured values for the field distribution along the X axis ( $y = 0$ ) and the results calculated from equation (15) by computer; the dots represent measured points and the solid line indicates the calculation results. It can be seen that the calculation results are in good agreement with the measurements.

Figure 5.

Measured field distribution

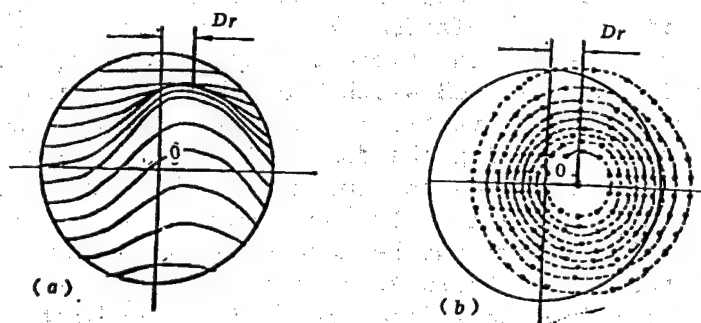
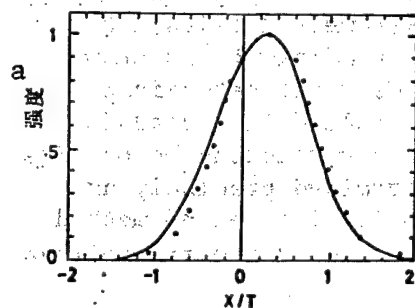


Figure 6. Comparison of measurements and calculation results

Key:

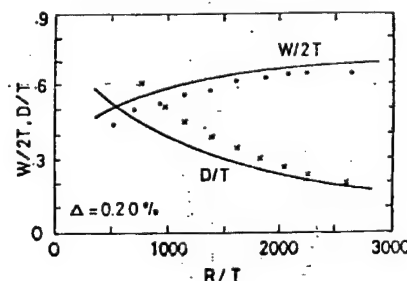
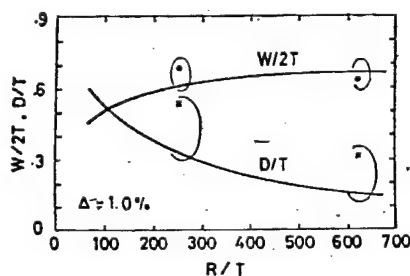
a. Intensity

We next considered the relationship between the change in the field distribution and the radius of curvature  $R$ , as shown in Figure 7. Here  $W/2T$  is the 3-dB width of the field distribution as a function of  $R$ , and  $D/T$  is the field deviation as a function of  $R$ . The solid curves represent the calculated values, and the dots and crosses represent measured values of  $W/2T$  and  $D/T$  respectively. Figure 7 shows that the field distribution in a fiber will be distorted, not only departing from the fiber axis in the direction of the radius of curvature, but also showing a narrowing of the field distribution pattern. The figure also indicates that the pattern becomes increasingly narrow as  $R$  decreases and the deviation increases, thus proving that the theoretical analysis agrees with the experimental results.

Finally, we compare the approximate theory of Kawakami et al. with Marcuse's theory presented in Ref 1. The plots of  $D/T$  and  $W/2T$  shown as solid lines in Figure 8 are calculated from equation (15), derived from the Kawakami theory, while the dots and crosses represent the results obtained by making an allowance for the strain effect,  $(1 + \frac{ce}{n}) = 0.8$ . In the calculation we used  $v = 2.4$ ,  $n_0 = 1.51$  and  $\Delta = 1.0$  percent. It is evident from Figure 8 that the values of  $W/2T$  calculated in Ref 1 increase somewhat as  $R$  decreases, which is at odds with the experimental results. In addition, the deviation  $D/T$  differs considerably from the actual results, particularly for large values of  $R$ . From these facts we can conclude that Kawakami's approximate analysis of the field distribution in a bent single-mode fiber (equation (15)) is more correct than that presented in Ref 1.

Figure 7.

Change in field distribution versus radius  $R$



← Figure 8.

Comparison of experimental results with two theories

**Acknowledgements.** The theoretical and experimental analysis presented here and the experiments were completed in the Kawakami laboratory at Tohoku University, Japan, with constant guidance and assistance from Professor Kawakami Shojiro and Assistant Professor Miyagi Mitsunobu; we take this occasion to express our deep gratitude.

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APPLIED SCIENCES

KrCl-XeCl DOUBLE LASER OSCILLATION REPORTED

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[Article by Ma Shusen [7456 2885 2773], Yao Yongbang [1202 3057 6721], Shan Xinxin [0810 2450 2450], Zhu Jikang [4376 4949 1660], Qin Yuying [4440 3768 5391], Wang Guangchang [3769 1639 2490], and Cai Lianxin [5591 6647 2450], Anhui Institute of Optics and Precision Mechanics, CAS: "Double Oscillation in a KrCl-XeCl Excimer Laser"]

[Text] Abstract. Double laser oscillation from KrCl and XeCl on the same discharge pulse was obtained in a Kr-Xe-HCl-He gas mixture. The KrCl emission was about 12 ns later than the XeCl emission. The xenon partial pressure is critical to double oscillation.

1. Introduction

In an earlier investigation, simultaneous laser oscillation was obtained from XeBr and XeCl<sup>1</sup>; Reference 2 reports simultaneous oscillation from KrF and ArF. Recently we obtained double lasing from KrCl and XeCl in a fast discharge excimer laser, with outputs at 222 nm (KrCl) and 308 nm (XeCl) from the same discharge pulse (Xe-Kr-HCl-He mixture).

2. Experimental Apparatus, Results, and Discussion

The experimental apparatus is shown in Figure 1. The laser structure and discharge network are those described in Reference 1. The electrode spacing was 2 cm and the active length was 72 cm. For the energy-storage capacitors,  $C = 0.1 \mu\text{F}$  with a storage voltage of  $V = 35 \text{ kV}$ . The gas mixture proportions were Xe:HCl:Kr:He = 3:7:120:1570 mbar. The He, Kr, and Xe had a purity exceeding 99.99 percent, while that for the HCl was over 99 percent. The spectrum was determined with a Carl Zeiss 2-meter grating spectrometer with a line dispersion of about  $8 \text{ \AA/mm}$ . A quartz prism was used as a beam splitter in the light path. The photodetector consisted of two high-current photomultipliers. The pulse waveforms were displayed on an oscilloscope.

Figures 2a and 2b show the laser output spectrum and density distribution. The density does not correctly indicate the relative intensities of the KrCl and XeCl emissions because the optical components in the light path and the

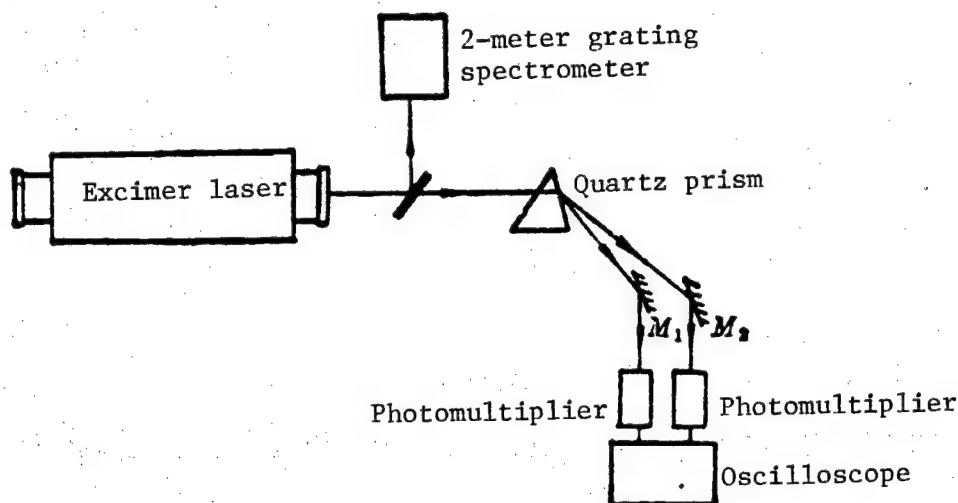


Figure 1. Experimental Measurement Apparatus

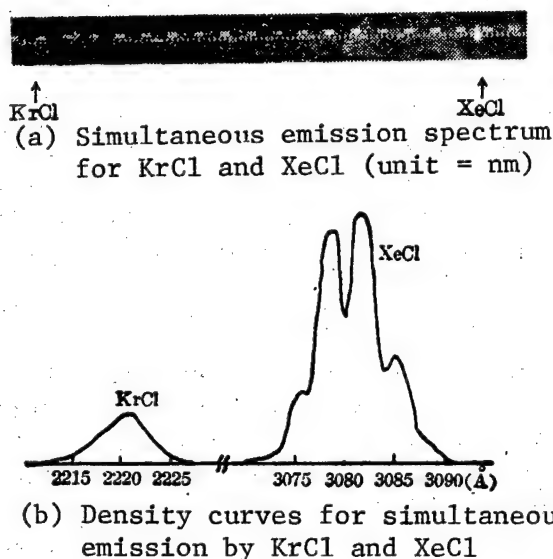
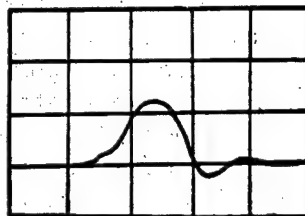
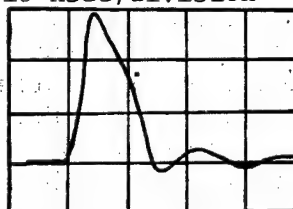


Figure 2.

spectrometer have greater losses for KrCl emissions than for XeCl emissions. Figure 3a shows the waveform for KrCl emissions without Xe present, while Figure 3b shows the waveform for XeCl emissions without Kr present. Figure 4a shows the KrCl output waveform with Xe present, and Figure 4b shows the XeCl waveform with Kr present. Figure 5 shows the oscillograph trace for KrCl and XeCl emissions incident on the two photomultipliers after dispersion by the prism. Before this trace was photographed, the XeCl laser beam was split and fed to both photomultipliers. The light path before these two beams entered the photomultipliers was essentially the same as the light paths for the KrCl and XeCl beams, and thus time delays produced by the optical path, the photomultipliers, and the wires to the oscilloscope were eliminated by superimposing the two XeCl waveforms on the oscilloscope display. When the KrCl and XeCl

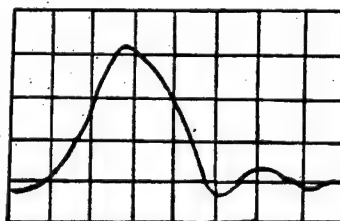


(a) KrCl laser pulse  
10 nsec/division

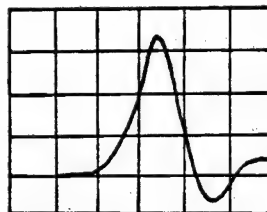


(b) XeCl pulse,  
10 ns/division

Figure 3.

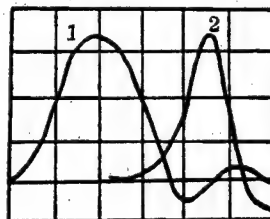


(a) KrCl laser pulse in gas  
containing Xe, 5 ns/division



(b) XeCl laser pulse in mixture  
containing Kr, 5 ns/division

Figure 4.



1. KrCl emissions  
2. XeCl emission

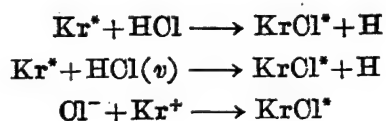
Figure 5. Pulses From Simultaneous Laser Emission by KrCl and XeCl, 5 ns/  
Division



emissions were both fed to the same photomultiplier without splitting in the prism, the oscilloscope trace also had two peaks and the duration was essentially the same as the total duration in Figure 5. This indicates that the KrCl and XeCl emissions were produced sequentially during the same discharge pulse; the KrCl emission occurred about 12 ns earlier. Comparison of Figures 3 and 4 shows that the introduction of Kr had no obvious effect on the XeCl waveform, while addition of Xe increased the width of the KrCl pulse.

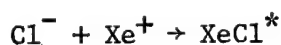
The total laser output intensity and the KrCl and XeCl intensities are related to the Xe, Kr, and HCl concentrations. The relative amount of Xe is the most critical: only at relatively small Xe concentrations can KrCl and XeCl emissions of essentially the same intensity be obtained. The Xe concentration was below 1 mbar. The total energy of the double oscillation and the partial energies were all weaker than emission by KrCl or XeCl in isolation. This indicates that Kr has a quenching effect on the lasing by XeCl and Xe has a quenching effect on lasing by KrCl. The experiment shows that it is the Xe that has the stronger effect. For a gas mixture of 3 mbar/Xe, 3 mbar/HCl and 1650 mbar/He at 33 kV, the XeCl output energy is 39 mJ; when 2.8 mbar Kr is introduced there is no change in the output energy, while when 30 mbar Kr is introduced the output energy is decreased to 7 mJ, about one-sixth of the original value, and no KrCl emission appears. For a mixture of 3 mbar/HCl, 140 mbar/Kr and 1650 mbar/He at 33 kV, the KrCl emission energy is 16.5 mJ; when about 2.8 mbar/Xe is introduced, XeCl emission also appears and the total output energy is only 2.3 mJ, while the KrCl emission energy is less than 2 mJ. When the concentration of Xe is increased to 4 mbar, there is essentially no KrCl emission. Thus Xe has a much stronger quenching effect on KrCl emissions.

The relative times of appearance of the laser pulses apparently indicates that the dynamic processes involved are not parallel. For KrCl the following process is still the principal pathway by which the population inversion is produced:



The reaction rate constant for KrCl is essentially the same as that for XeCl.<sup>4</sup> Because the concentration of Kr is much greater than that of Xe, the probability of collision between Xe\* and HCl is much smaller than that of collisions between Kr\* and HCl, so that initially most of the HCl reacts with Kr\* and thus the KrCl can achieve the inversion needed for lasing first. Because HCl also has a rather strong quenching effect on KrCl emissions, the problem cannot be solved by increasing the HCl concentration.

It is evident from the relative positions of the peaks in Figure 5 that the appearance of the XeCl output is related to the KrCl excited emission. The principal pathway by which XeCl\* is formed may be



where the Cl<sup>-</sup> is chiefly produced by electron collisions with the Cl that is generated after excited emission by KrCl\*.

The KrCl and XeCl pulses are in basically the same time relationship to the discharge current pulse.<sup>5</sup> In our experiment the discharge current pulse was the same for both, and accordingly the main reason that the KrCl emission appeared about 12 ns earlier than the XeCl emission was related to the nature of the dynamic process. Although the mixture contained only one halogen donor, the dynamic processes for the two were not parallel; this is a point of difference from the situation described in Reference 1.

It can be seen from a comparison of Figures 3 and 4 that the introduction of Xe lengthened the KrCl laser pulse by about 4 ns, while the presence of Kr shortened the XeCl pulse by about 3 ns. This circumstance may also be related to the nature of the dynamic process.

Comrade Wang Aihua [3769 1947 5478] measured the spectrum plates for us and drew the density curves, and Comrade Bao Jian [7637 0256] helped us in taking the oscilloscope photographs; we express our deep gratitude to both.

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APPLIED SCIENCES

EXPERTS URGE VIGOROUS DEVELOPMENT OF ASTRONAUTICS INDUSTRY

HK260707 Shanghai SHIJIE JINGJI DAOBAO in Chinese 30 Sep 85 p 2

[Report by SHIJIE JINGJI DAOBAO Beijing correspondent Xu Xiaowei [6079 1420 1792]: "A Forum on New Technological Revolution Calls for Greater Efforts To Develop the Astronautics Industry as a Leading Industry"]

[Text] The new world technological revolution has drawn attention for many years. What is the main area in which China should concentrate its efforts? At a forum on the new technological revolution held last week, scores of experts engaged in world economic, political, and scientific and technological research again stated: China's leading industry is the astronautics industry. If China does not make further efforts to develop its astronautics industry on the current basis, it will lag behind in the forthcoming era of space exploitation by man. The forum was sponsored by the editorial department of SHIJIE JINGJI DAOBAO.

Man's historical and scientific development shows that just as land development led to maritime exploitation, the 21st century will inevitably be a century of space exploitation. The experts forecast that in the next several decades, mankind will usher in a new momentous age of space exploitation.

For this reason, quite a few research personnel are keenly anxious to develop China's astronautics industry. They said that in view of the future of mankind, we will make a mistake of great magnitude if we fail to attach special importance to developing the astronautics industry now. They stressed that this is a major policy decision vital to the state's future development and that if we fail to make a strong decision on this matter, we shall not lag behind by several decades but probably by several centuries.

The experts pointed out: China can, and must, occupy a certain position in the exploitation and use of outer space. It is believed that, of all the other new technologies and industries, China's astronautics industry is closest to the world level. Moreover, the development of the astronautics industry also includes the development of new technologies, including microelectronics, new energy resources, new materials, and bioengineering. If we take the astronautics industry as the main area in which we should concentrate our efforts, it will serve as a "dragon head." If we fail to grasp this "dragon head," we shall lose the main area in our efforts to meet the

challenge of the new world technological revolution, and it will be impossible to develop other new technologies and industries satisfactorily.

At present, all countries with the necessary facilities emphasize the development of the astronautics industry. Even some developing countries are unwilling to lag behind. With strategic insight they compare this to the payment of children's tuition fees, which will bring them unlimited benefits in the future. Besides, according to some experts' analyses, the economic returns of the astronautics industry are amazingly high. Take the United States for example. The ratio between input and output over a decade is about 1 to 50. In addition, it will also bring about incredible changes to human life politically, economically, and scientifically. The prospects are magnificent. The experts said that the scale of China's astronautics industry in the Seventh Five-Year Plan period should be larger than that during the Sixth Five-Year Plan period in order to keep pace with the development of the world astronautics industry. If it is maintained at the level of the Sixth Five-Year Plan period, it will probably result in retrogression. It is necessary to make a clear-cut policy decision on this matter.

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APPLIED SCIENCES

PROGRESS IN CHINA'S GEOPHYSICAL, GEOCHEMICAL EXPLORATION REVIEWED

Beijing ZHONGGUO DIZHI [CHINA GEOLOGY] in Chinese No 9, 1984 pp 17-21

[Article by Zou Guanghua [6760 0342 5478] of the Geophysical Prospecting Bureau, Ministry of Geology and Mineral Resources: "China's Progress in Geophysical and Geochemical Exploration Work"]

[Text] Geophysical and geochemical prospecting work in China has been closely coordinated with geology and mine prospecting projects over the past 35 years. It has played a vanguard role in all spheres and stages of geological work, and it has made a contribution to proving mineral product resources and supplying geological data. Since the 3rd Plenum of the 11th CPC Central Committee, the elimination of chaos and restoration of order on the entire geology front and the adherence to the principle of geology and mineral exploration as the core have brought geophysical and geochemical prospecting work onto the path of healthy development, expanded the range of applications and opened up the realm of services. They now have become two independent disciplines in earth science research.

I

Regional geophysical and geochemical prospecting work is basic survey work that is of strategic significance. The effective coverage area of aeromagnetic surveys done in China over the past 30-plus years now exceeds 9.30 million square kilometers (including 1.20 million square kilometers of ocean). Apart from Taiwan island and the surrounding area and parts of the southern East China Sea and southern South China Sea, aeromagnetic work basically has been completed in all areas east of 102 east longitude. On the basis of full utilization of gravitational data from fraternal departments, regional gravity surveys with unified technical requirements covering an area of 4.20 million square kilometers have been undertaken in more than 20 provinces and autonomous regions. Traverse metal measurements covering several million square kilometers were done in conjunction with 1:200,000 regional geological surveys beginning in the 1950's.

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Note: This article does not include oil and gas prospecting work done by staffs under the Petroleum and Marine Geology Survey Bureau.

Improvements in sampling distributions and analytical techniques in recent years have permitted second generation regional geophysical prospecting work to get underway in more than 20 provinces and autonomous regions. All of this work has provided important basic information for basic geological research and mineral surveys. Now, 1:1,000,000 aeromagnetic charts have been completed for the area east of 102 east longitude and a 1:4,000,000 aeromagnetic chart for China has been published. A 1x1 national average grid gravity map based on existing gravitational data has been drawn, as have free space and grid gravity charts for three-fourths of the country. In addition, more than 20 provinces and autonomous regions have compiled geophysical and geochemical prospecting maps for entire provinces and important prospective mineralization regions.

Regional geophysical and geochemical prospecting data provides much important new information concerning the demarcation of geodesic structural elements, studying the formation and structure of the crystallized basement, making inferences about the location and scale of certain deep fracture zones, delineating geological factors that control mineralization (intrusive rock, fractures, alternation zones, etc.), demarcating prospective mineralization zones, making mineralization predictions and so on.

According to aeromagnetic data over a large area, we have explored basement uplifts, sediment thicknesses and structural layouts in China's Songliao, Huabei, [North China], Tarim and other sedimentary basins, and we have discovered and delineated large scale petroliferous depressions in the Beibu Gulf, Pearl River Mouth, East China Sea, southern Yellow Sea and other regions, which has made an important contribution to providing directions in the search for oil and speeded up exploration for oil and gas resources. In addition, we have delineated the distribution of basic, ultrabasic and some moderately acidic intrusive rock and discovered or confirmed more than 10 deep large fracture zones at Tanlu, Yarlung Zangbo Jiang, north Qiling and other places. With a focus on gravitational data, we have integrated with other types of data for the first suggestion that there are two zones of acute changes in thickness in China at Daxing'anling--Taixing Shan--Wuling Shan and Helan Shan--Longmen Shan. They not only are of great significance for research on geodesic structures in China but also play a controlling role in the formation and distribution of endogenous mineral products.

Reprocessing of 1:200,000 traverse metal measurement data for copper, lead and other elements has provided basic information on prospective mineralization zones for most of the provinces and autonomous regions in China. Basic geological research in second generation regional geophysical prospecting work now is underway and it has revealed its superiority in prospective mineralization zones.

Geophysical investigations of deep strata involves basic and forerunning work. It not only is of great significance for research on the

regularities of mineral formation but also promotes development of the earth sciences as a whole. It was only begun in the ministry in recent years. The Chinese Academy of Sciences and the French Scientific Research Center undertook cooperative research on "Geological Structures of the Himalayan Mountains and the Formation and Evolution of the Crust and Upper Mantle" in 1980-1982. They employed natural seismology, artificial seismology, magnetic geodesic currents and other methods and made important progress in the study of the geophysics of deep strata. Their work has attracted the attention of scholars in China and abroad.

Pleasing achievements also have been made in geophysical and geochemical prospecting work in the area of 1:50,000 regional surveys of prospective mineralization regions (zones). The results of work done in the Lucong Basin in Anhui Province indicate that it may aid in solving certain basic geological questions and improving the results of mineral exploration. The degree of work within the basin is high and it is rich in mineral resources. Gravitational, aeromagnetic, and geochemical prospecting data at a 1:50,000 scale confirmed the concealed boundary beneath the red bed cap in the western part of the basin that had been debated for a long time. Typical volcanic structures were demarcated successfully. It has been inferred that concealed rock bodies exist beneath the capping strata of volcanic rock. Furthermore, it has been combined with the delineation of levels I and II mineralization regions within the mineral controlling structures in the region, and anomalous iron, copper and iron sulfide mineralization points have been noted now in several locations.

## II

Energy resource mineral products are the strategic focus of geology work. Beginning in the 1950's, a great deal of coal field geophysical prospecting work was done in several important coal fields on the North China platform (including Pingding Shan and Huaibei) and in the coal-short regions of the south. The information was used mainly to delineate coal-bearing basins, the distributional range of coal system strata, exploration of coal field structures, investigation and discovery of coal strata that were lost or became thinner during drilling, determination of coal seam thicknesses, depth, drilling project parameters and other questions. Excellent geological and economic results were obtained, especially in that the test wells have become an indispensable measure for use in coal field surveys and exploration. Based on the ministry's need to deploy for development of a national coal resources survey and coal field survey and exploration, geophysical prospecting work in coal fields has been reinforced or re-opened in 19 provinces and autonomous regions including Nei Monggol in recent years. It started with the handling and analysis of existing aeromagnetic, gravity and electrical depth measurement data. Preliminary results have been obtained in the demarcation of faults with a drop greater than 30 meters and rather good coal formation conditions that were measured using the frequency discrimination seismic method in Henan Province's Yongcheng Coal Field. Test wells in coal fields have continued to obtain obvious economic results and fill in inadequacies in exploratory drilling.

Geothermal geophysical prospecting work only developed on a rather wide scale during the 1970's and is concentrated mainly in prospective regions in Yunnan, Xizang, Beijing, Tianjin, Fujian, Guangdong and other places. The Yangbajing geothermal field in Xizang used geophysical prospecting methods that mainly involved electrical methods supplemented by gravity and magnetic methods to delineate a geothermal field covering 14 square kilometers as well as the locations of conjuncture of two groups of fractures that are the most favorable for the extraction of hot steam. Moreover, the distribution of concealed intrusive rock bodies was delineated, all of this providing a foundation for research on heat sources. The drill encountered hot steam at high temperatures and under rather high pressures, the maximum temperature reaching 171 degrees C at a well mouth pressure of 4 to 5 atmospheres. It already has become a famous high temperature geothermal field in China.

Good results continue to arise from the use of radioactive measurement methods in the search for uranium in northern Guangdong, western Sichuan, Zhejiang, and other areas, and uranium ore strata have been discovered in the bore holes of some old mining regions.

### III

Geophysical and geochemical prospecting work for metallic and nonmetallic minerals lies within the realm of most work done by comprehensive geophysical and geochemical prospecting teams. Work has been developed on more than 60 types of minerals over the past 30-plus years. The targets have been ferrous metals, nonferrous metals, and precious metals. Geophysical and geochemical prospecting has developed rather quickly in mineral product surveys and plays a vanguard role. It uses anomalies as clues in the search for minerals and has done project experimental verification and geological evaluations to discover or expand several mineral product areas or mineral deposits. It has speeded up progress in mineral product survey exploration and has had its best results in the search for blind deposits and concealed deposits in broad capped regions.

The results have been most obvious in the use of magnetic methods, especially aeromagnetic methods, in rapid searches for magnetite deposits formed by various causes. According to incomplete statistics, aeromagnetic anomalies used as clues in mineral exploration have led to the discovery or expansion of iron ore deposits or mineral product areas in 358 locations. Most magnetite ore deposits in China were discovered using geophysical prospecting data. Examples include those at Panxi in Sichuan, eastern Hebei, Lu Jiang in Anhui and others which have played an important role in the construction of several large scale iron and steel base areas in China. Moreover, iron ore has been found repeatedly in areas such as Heiying Shan in Nei Monggol, Baicao-Fanjiatian in Sichuan, Yemaquan in Qinghai, Ma'anshan in Anhui, Chengde in Hebei and other places.

Magnetic, electrical and geochemical methods have been applied effectively in the search for certain precious and heavy metals and nonferrous metal ore deposits. This is especially true of the conditions associated with



magnetic minerals or sulfide minerals, where the results of "direct" prospecting for minerals using geophysical prospecting have been obvious. Good results were obtained during the 1950's and 1960's in survey exploration of several large scale ore deposits. Examples include the copper ore at Guoluo and Sashitang in Qinghai, lead and zinc ore at Yichun in Heilongjiang, multiple metal ores at Xinxing in Guangdong, the silver, arsenic, lead, and zinc deposits at Guiyang in Hunan and others. In recent years, investigation and verification of aeromagnetic anomalies has led to the discovery of iron polymetallic deposits at Wu County in Jiangsu Province, tin ore at Linwu in Hunan, and others. Electrical excitation, especially high power electrical excitation, anomalies have been used as clues and tests have led to the discovery of molybdenum ore at Changgangling in Yongji, Jilin, molybdenum and lead deposits at Luonan in Shaanxi and so on, and there have been new expansions around the Bainaimiao copper mine region in Nei Monggol. The regional development of geochemical prospecting work and advances in sampling methods and analysis of techniques have led to obvious continual improvements in geological mineral prospecting with geochemical prospecting. Research on the mineral-forming elements in various types of natural materials and on changes in the content of associated elements rather directly reveals the possible distribution of certain mineral products and has become the main indicator in mineral exploration. According to incomplete statistics, project testing and verification has led to discovery or expansion of 80 mineral deposits or mineral product areas in the last 5-plus years, mainly based on geochemical prospecting anomalies, including 43 nonferrous deposits, 24 precious metal deposits and 13 tin deposits. There are large scale deposits at more than 30 locations including the Duchang tungsten and molybdenum deposit in Jiangxi, the tin and vanadium deposit at Xingshan in Hubei, the gold deposit at Luoning and the molybdenum deposit and Leimengou in Henan and others.

Geophysical and geochemical prospecting methods have achieved excellent results in the search for chromium, nickel, and platinum family metals related to basic and ultrabasic rock and for primary deposits of diamonds and other mineral products under favorable conditions. Large area aeromagnetic work has discovered and delineated more than 500 basic and ultrabasic rock bodies that suggest prospective areas in surveys for the above mineral products. Comprehensive application of magnetism, gravity, electricity, geochemical prospecting, and other methods in rock bodies also has led to the discovery of several ore deposits or mineral product regions.

The daily increasing importance of nonmetallic mineral products in China's economic construction has led many provinces and autonomous regions to strengthen geophysical and geochemical prospecting work for nonmetallic minerals in recent years. Work has been developed for almost 20 types of minerals including sulfur, phosphorous, potash, graphite, asbestos, gypsum, and others. Graphite has excellent conduction properties and the electrical method has been utilized effectively to pursue and discover concealed graphite deposits at Jiaodong in Shandong, Luobei in Heilongjiang, Yichang-Xingshan in Hubei, Danfeng in Shaanxi, and other

places. The Longyao gypsum mining region in Hebei applied the electrical method based on the different electrical characteristics of the gypsum strata and the upper and lower plates to delineate the distributional scope of the mineral strata. Thick strata of gypsum were found within most of the inferred and visible depth of the deposit, which improved economic results. It now has been confirmed to be a large scale gypsum deposit. Saline rock strata generally exhibit obvious differences in density compared with the surrounding rock. Since the discovery of large scale saline mineral deposits on the basis of gravity data at Dingyuan in Anhui, Hengyang in Hunan, Jiangcheng in Yunnan, Tai'an in Shandong, and other places through the 1960's, the scope of a saline basin was delineated on the basis of gravitational anomalies in the Anning region of Yunnan and it was predicted on the basis of this that there were two rich saline accumulation segments. The results were that gypsum, glauberite and thick strata of halite were encountered during exploratory drilling and they occur on a large scale. Later, a 25 square kilometer negative gravitational anomaly was delineated in the Fumin Basin north of Anning, and exploratory drilling confirmed that there were rather thick halite strata in the deep parts. The results of using electrical methods to search for deposits of the excellent conductor pyrite have been excellent. A rather rich blind deposit of iron sulfide ore was discovered in 1983 on the basis of electrical activation data in the Lu Jiang and Huangtun regions of Anhui, and hematite strata containing 37.4 percent iron exist below them. It is a pyrite region with good prospects. In addition, they also have played a role to different degrees in the discovery and expansion of the large Kuandian and Yingkou boron deposits and the large and medium sized asbestos deposits at Luda in Liaoning, the unusually large natural soda deposit at Tongbai in Henan, the large scale phosphorous mine at Yexian in Shandong, the alunite deposit at Jiangjun Shan in Shandong, the fluorite deposit at Dibei in Guangdong and the medium sized barite deposits at Yiliang and Malong in Yunnan.

Geophysical prospecting in wells is an effective measure in the search for blind deposits in deep strata. The large scale development of iron ore survey work during the 1970's brought on major developments in magnetic measurements in wells. Work has been developed in more than 160 magnetite regions or areas of gravitational anomalies in 26 provinces and autonomous regions. The thickness and formational shape of the ore bodies drilled through is understood and a group of blind deposits beside and below wells have been found, which has increased iron ore reserves. Excellent results have been achieved at Jidong [eastern Hebei], and Suixi in Anhui and other iron ore regions.

Development work on test wells for metallic and nonmetallic minerals began in the 1950's, but the rather complex physical characteristics of most metallic and nonmetallic deposits and the difficulty of examining and verifying cores from the well walls meant that the results were not as obvious as those in coal fields. Apart from its use to classify strata and determine their thickness, applied test well data has been a beneficial supplement for research on ore varieties. Based on analysis of the relationships between the physical parameters of ores and the amount of

minerals they contain, radioactive gamma test wells have been utilized for determining the grade of ore in the glauberite and gypsum mining regions of eastern and southern Sichuan and the phosphorous deposit areas in Weng'an in Guizhou, and magnetization rate test wells have been applied to meet the needs of experimental chemical analysis of ore grades in the Hongge iron ore region of Sichuan. The results of grade determinations from test wells have been used to calculate reserves.

Increased levels of work in eastern China, the development of frontier regions in the west and the multifaceted needs of national economic construction for mineral product resources have meant that there has been a tendency toward a continual expansion in the scope of work faced by geophysical and geochemical prospecting and toward ever-increasing difficulties in finding minerals. The fact that the physical prerequisites for direct use of geophysical prospecting methods in the direct search for minerals have not been prepared for metallic and nonmetallic minerals means that there are no obvious physical differences between the minerals and the surrounding rock. The depth of exploration has increased and this has been accompanied by the development of mineral exploration work in difficult regions (in frontier regions without convenient communications, mountainous areas, etc.). This has restricted the results of geophysical prospecting in the direct search for mineral deposits. Based in the principle of "making full use of the role of geophysical prospecting for indirect mineral exploration and filling in geological charts" as proposed by the National Geophysical and Geochemical Prospecting Work Conference in 1981, many geophysical prospecting teams have made successful applications and used investigations of the geological factors that control mineral formation and the indicators associated with mineral bodies to reach their goals in mineral exploration.

#### IV

Geophysical prospecting work in hydrology projects has the characteristics of "small investments, short schedules and good results." The needs of people's lives and social development have made this work increasingly important. Effective hydrological geophysical prospecting work has been done for well drilling to relieve drought in the Huang He, Huai He, and Hai He region, in Jixuhuai, the Hexi Corridor, the basins of Shanxi, and other arid and semi-arid northern regions, and it has made important contributions to providing water for industrial and agricultural uses and for evaluating water resources. Examples include the electrical depth measurements and electrical well measurements over more than two-thirds of the Huang-Hai-Hai Plain that have made a preliminary investigation of freshwater boundaries, zones of rich freshwater accumulation in shallow strata and the locations of ancient river channels, and they have delineated freshwater, slightly saline, semi-saline and saline water contours. On the basis of this data, they also have integrated with geological conditions to determine locations for nearly 1 million water wells, 80 to 90 percent of which hit water (the figure reached 100 percent

in some areas). According to estimates, the state conserved roughly 1 billion yuan in expenditures for the cost of drilling the wells alone. This has greatly promoted the development of industrial and agricultural production in this region. The collection and analysis of a large amount of electrical depth measurements and electrical well measurement data now is in process within the region and various types of hydrological geophysical prospecting maps have been drawn. Achievements also have been made in recent years in the search for water in the Huaiyin-Siyang-Lianshui region of Jiangsu, in Sichuan's Chengdu Plain, in Xinjiang's Urumqi He river basin and other areas. Hydrological geophysical prospecting work has developed quickly in cities with water shortages and industrial and mining regions. Almost 50 cities use geophysical prospecting to guide the drilling of wells and excellent geological and economic results have been obtained. Geophysical prospecting work also has provided underground water resources for farmland irrigation and expanded the irrigated area.

Hydrological well measurements have been integrated closely with exploratory drilling. It has permitted rather accurate determination of aqueous strata and the degree of mineralization in strata water. No coring has been done in parts or all of the Quarternary strata in some regions. This not only has conserved on exploratory drilling expenses and improved the efficiency of exploratory drilling but also has improved the quality of geological information. Beijing Municipality, for example, basically did no coring in all of the Quarternary strata encountered during hydrological drilling. The total length of the Quarternary system in 1980 was only about 2,500 meters. The use of well measurement data and the lack of coring during drilling saved about 190,000 yuan in exploratory drilling costs. Moreover, the well measurement costs were only 2.4 percent of the costs of exploratory drilling and the economic results were obvious. Similar results also have been obtained in hydrological well measurements in Jilin, Guangdong and other provinces and autonomous regions.

There has been a continual increase in the amount of engineering geophysical prospecting work as a result of the need for preparatory prospecting work for planned construction projects and key construction projects in central cities and important economic regions, and new realms of urban geophysical prospecting have been opened up. There are broad prospects for application and concerns geophysical and geochemical prospecting work, site selection for important projects, water supply exploration, geothermal investigations and other aspects of 1:50,000 regional surveys in cities and surrounding regions. Provincial [geology] bureaus in Guangdong, Fujian and other provinces have adhered actively to the spirit of "taking the initiative in services" and excellent results have been obtained.

Although geophysical and geochemical prospecting work in China has developed in a major way and achieved obvious results in the 35 years since the nation was founded, it still does not meet the needs of geological and mineral product tasks as a vanguard in geological work. To subordinate to

and serve the overall goals and tasks of geological work and to meet the challenge of the new technological revolution, we must strengthen geophysical and geochemical prospecting work, improve levels of modernization in geophysical and geochemical prospecting work, and improve the results of geological mineral exploration and the economic and social results of geophysical and geochemical prospecting work.

Comrades Yang Guangqing [2799 0342 1987], Sun Wenke [1327 2429 3784], Yuan Xuecheng [5913 1331 6134] and Zeng Fanchao [2582 0416 6389] provided valuable opinions for this article and I would like to express my thanks.

12539/13012  
CSO: 4008/72

JPRS-CST-85-041  
10 December 1985

## BRIEFS

ATOMIC LASER ISOTOPE SEPARATION--Beijing, 19 Nov (XINHUA)--A new technology to separate atomic uranium 235 and 238, called atomic developed laser isotope separation, was recently announced as successful by the Nuclear Industry Ministry. The technique increases the density of uranium 235 to meet the requirements of nuclear reactor fuels after one separation, according to a ministry official. He said the new technology could save half the cost of the expensive diffusion process, the traditional method for uranium isotopic splitting in China. The ministry official acknowledged that it would be some time before the new technology could be used in the nuclear industry. [Text] [Beijing XINHUA in English 0159 GMT 19 Nov 85] /9604

DATA ON GIACOBINI-ZINNER--Nanjing, 5 Nov (XINHUA)--A Chinese observatory has worked out the orbit of a comet passing close to Halley's, providing data useful in the operation of a rocket sent to observe Halley's Comet, according to the astronomical organization, International Halley Watch. The organization disclosed that the Zijinshan (Purple Mountain) observatory in Nanjing, capital of Jiangsu Province, has delivered precise positioning data of the Giacobini-Zinner comet. All the information was found accurate and helped the spaceship "International Cometary Explorer" reach its planned position. As it is not equipped with navigation facilities, the [spacecraft] relies on precise measurement of its position from earth. The International Halley Watch Program has organized observatories all over the world to jointly observe the comet as it approaches the earth this year. The [spacecraft] passed 7,900 km from the nucleus of Halley's Comet 11 September. [Text] [Beijing XINHUA in English 1036 GMT 5 Nov 85] /9604

CHINA COULD LEAD SCIENCE--Beijing, 11 Nov (XINHUA)--China is likely to lead the world in scientific research in a number of fields, including mathematics and astronomy, by 2000, predicts an official report in today's ECONOMIC DAILY. The report, entitled "China's Science and Technology by 2000," says that by then, the country's overall technology will have reached the standards of developed countries in the late 1970s and early 1980s. But technology in oil and petrochemical industries, mechanics, and microelectronics will have reached the 1990s standards of the developed world. The report is based on a 2-year research program backed by the State Council and the Chinese Academy of Social Sciences. The development of science and technology will increase the competitiveness of China's economy, it says. By 2000, most of China's industry will be using modern equipment, and high-tech industries will play a major part in the national economy. [Text] [Beijing XINHUA in English 1055 GMT 11 Nov 85] /9604

ENVIRONMENTAL QUALITY

JPRS-CST-85-041  
10 December 1985

SULFUR DIOXIDE POLLUTION SURVEYED IN SICHUAN PROVINCE

OW111150 Beijing XINHUA in English 1125 GMT 11 Oct 85

[Text] Chengdu, 11 Oct (XINHUA)--Sichuan scientists are of the opinion that sulfur dioxide in the atmosphere could be reduced by supplying fine quality coal to urban residents and factories.

The proposition was the result of a province-wide survey aimed at determining what the environment should be like in the year 2000. The study, which began a year ago, covered the atmosphere, water, energy sources, noise and waste.

It is part of a national program sponsored by the State Council Development Strategy Research Center and the Ministry of Urban and Rural Construction and Environmental Protection. Sichuan is the first province to complete the work.

Scientists found that about 90 percent of the sulfur dioxide and other particles in the atmosphere came from the burning of coal. They proposed building coal gasification plants in Chengdu, Chongqing and other big cities and expanding the province's coal dressing capacity.

Sichuan, with a population of 100 million, bans the building of new factories that fail to meet pollution protection standards. A plan has been drawn up to improve pollution control in existing factories and mines. Factories which present major difficulties will be converted to other lines or shut down, according to provincial authorities.

A number of metallurgy, petroleum and chemical enterprises have now brought pollution under control and a better ecology has been achieved in many villages.

Dukou, an iron and steel center, has increased the subtropical trees and plants growing around the plant through residue treatment and afforestation.

Noise pollution on nine thoroughfares in Sichuan's capital of Chengdu has been reduced from 79 to 67 decibels since 1979. The state has set a standard of 70 decibels.

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CSO: 4010/1015

## ENVIRONMENTAL QUALITY

### CHINA'S CITIES URGED TO CLEAN UP POLLUTION

HK120614 Beijing CHINA DAILY in English 12 Oct 85 p 1

[Article by staff reporter Wang Gangyi]

[Text] Luoyang--China's cities are being urged to draw up urgent programmes to tackle the looming threat of urban pollution.

Only full-scale planning by city governments can halt the deterioration of the country's urban environments, said Zhao Weichen, deputy director of the Environmental Protection Committee under the State Council yesterday.

He told a national conference in Luoyang on the urban environment that 90 percent of water resources around Chinese cities were now polluted by untreated waste.

Dust in the air of all northern Chinese cities now exceeds state-set standards, while in the southwest, the phenomenon of "acid rain" is growing, said Zhao. He said all city governments should list environmental protection as a fundamental task, with mayors taking immediate leadership.

Environmental protection, planning, urban construction and other city departments should help work out overall protection programmes as soon as possible, and mobilize all urban residents to take part.

"Mayors should take responsibility for the environmental quality of their cities by launching and exercising leadership in the campaigns," Zhao said.

Only with unified programming by city governments and direct leadership by mayors can cities improve their environment.

Sponsored by the Environmental Protection Committee, the Luoyang conference will discuss the goals, principles, policies and specific measures for environmental protection in the country's major cities during the Seventh Five-Year Plan period (1986-90).



Zhao said the tasks included:

Solving air pollution by rationally utilizing coal, improving urban heating systems and popularizing gas cooking;

Protecting water resources by setting up drinking water protection areas, rationing industrial water consumption, establishing more waste water recycling plants and dredging rivers and lakes in urban areas;

Recycling the rapidly increasing volume of garbage in urban areas, and;

Controlling noise and increasing green cover.

To ensure the success of these measures all cities should work out both overall programmes for the 5-year plan period and programmes for each of the 5 years, Zhao said.

City governments should also gradually increase investment in environmental protection projects as their economy develops. Fund-raising campaigns may be launched to collect money from enterprises and individuals.

"The principle that he who causes pollution should be responsible for its improvement will guide urban environmental protection," he said.

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CSO: 4010/1015

ENVIRONMENTAL QUALITY

POLLUTION CONTROL EFFORTS REPORTED IN CHONGQING

OW161109 Beijing XINHUA in English 1049 GMT 16 Oct 85

[Text] Chongqing, 16 Oct (XINHUA)--Chongqing's environmental monitoring center plays an important pollution control role in one of China's most populous cities.

The center's 141 branches have helped the nine city districts and 12 counties under the city's jurisdiction set up environment protection offices and stations. Chongqing has 7,000 industrial enterprises and the pollution problem is fairly severe.

Thirty plants now regularly monitor water quality at 13 locations on the Yangtze River, which runs through the city. Atmospheric pollution is tested at 16 spots. Thirty-one permanent monitoring stations have been set up in the city suburbs to collect pollution data.

The center has compiled a report on environment quality appraisal on the basis of the monitoring activities.

Scientists at the center have helped the Chinese Academy of Sciences study acid rain in southwest China by collecting data in Chongqing over the past 3 years.

Another report compiled by the center, on analysis of industrial waste water and gas, now provides the scientific basis for the city government to take legal action against factories violating pollution standards.

/9604

CSO: 4010/1015

ENVIRONMENTAL QUALITY

CHINA INTENSIFIES URBAN ENVIRONMENTAL WORK

OW250814 Beijing XINHUA in English 0732 GMT 25 Oct 85

[Text] Zhengzhou, 25 Oct (XINHUA)--China is intensifying work on control of environmental pollution in its cities.

Between March and September this year, 105 soot-free zones were designated and more than 13,000 coal-fueled boilers were fitted with smoke control devices in some cities, an official from the State Environmental Protection Bureau said today.

The control of air, water and noise pollution is being stressed particularly in China's major cities and scenic spots.

Beijing has made great efforts in the past few years to dredge dirty moats and river courses around the city. Now fish are being raised in the moat in the northern part of the city.

Six of Shanghai's 12 districts have been designated as soot-free zones and the rest will become so by the end of this year.

The authorities of Hangzhou, Zhejiang Province, have been fairly successful at improving the environment of the West Lake. They have allocated 8 million yuan for a water conversion project which will recycle the lake water every month when completed.

The official said that by the turn of the century more than 400 million people will live in Chinese cities and towns and the urban population will increase from the 1980's 20 percent to 40 percent.

Therefore to provide a pleasant environment is vitally important for the livelihood of the people as well as for economic development, he said.

/9604

CSO: 4010/1015

## SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

### LANZHOU PETROCHEMICAL ENGINEERING DESIGN INSTITUTE RECRUITS

Lanzhou HECHENG XIANGJIAO GONGYE [SYNTHETIC RUBBER INDUSTRY] in Chinese Vol 8, No 4, Jul 85 inside back cover

[Text] The Lanzhou Petrochemical Engineering Design Institute reports directly to the headquarters of the Chinese Petrochemical Engineering Co. [SINOPEC] It was formerly the No 5 Design Institute of the Ministry of Chemical Industry and was founded in 1958. It is one of the first organizations in China to undertake petrochemical engineering design work. The Institute is located in the nationally renowned land of fruits--Lanzhou--and stands on the northern edge of the Nanshan Park now under construction.

This Institute has a long history and solid technical expertise. It offers a complete range of exploration and design specialties and enjoy a certain prestige both at home and abroad. Over 450 technical personnel are now employed with the rank of engineer or higher, specializing in 20 areas: inorganic technologies; organic technologies; chemical instrument and meter automation; chemical engineering facilities; industrial boilers; machine repair, hoisting and transportation; electrical devices and telecommunications; heat supply; heating and ventilation; building structures; architecture; water supply and drainage; technology and economics; budgetary estimates; master plans, computer hardware and software; engineering surveying; and engineering geology. We are state-certified to provide exploration and design services and have a pressurized-vessel design permit. The Institute is currently negotiating with the Kellogg Co. of the United States to set up a joint engineering service so that it can provide abroad excellent design services for petrochemical equipment, synthetic ammonia and chemical products, all kinds of civic buildings, machines and equipment for the chemical industry, industrial and residential boilers, and energy-saving modifications of equipment. The Institute has an advanced computer station and a complete duplication facility. The library occupies an area of over 1,700 square meters with a collection of more than 60,000 technical books. The automatic control center and budgetary estimation center of the Sino-Petrochemical Engineering Co. are located at the Institute. The journal "LIAN YOU HUAGONG ZIDONGHU [AUTOMATION OF REFINERY ENGINEERING]" edited and published by the Institute, is distributed throughout the country.

Since the founding of the Institute, the design of 221 engineering facilities for 76 factories have been completed. Among them, 9 projects of large and

medium-size plant design are rather advanced by current domestic standards, 10 items of technical achievement have received citations at the National Scientific Meeting, and 14 items have received ministerial commendations. Of the 12 excellent design projects announced by the Chinese Petrochemical Engineering Co. in 1984, 3 were from this Institute. The butadiene production facility designed by us for the Jihua Co. received the national outstanding design gold medal at the National Outstanding Design Award Ceremony held in Beijing in January 1985.

In order to extend technical exchanges of the Institute with the outside, more than 50 technical personnel have been chosen in the past 2 years to go abroad on a tour of investigation and to engage in collaborative design. From now on, this will be extended further.

This Institute has adhered to the general policy of reform and development. It respects knowledge and talent. People with special training and college graduates from all over the country are welcome to join and devote their talent to distinguish themselves in the petrochemical engineering design of China. The Institute guarantees a job suited to one's special training so that individual talent can be fully exploited. It arranges for periodic release from work to take refresher courses and promotes professional leave for individual investigation and study. The Institute offers generous compensation and fringe benefits.

12922/7051

CSO: 4008/1081

10 December 1985

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/9365

CSO: 4008/1015

PUBLICATIONS

BRIEFS

HYDROPOWER ALMANAC--Beijing, 23 Oct (XINHUA)--An almanac on China's hydroelectric power generation has come off the press. The book, "China Hydroelectric Generation Almanac," provides detailed information on the development of China's hydropower industry since the founding of the Republic. Consisting of more than 1.5 million characters, the almanac also introduces, in detail, China's large and medium-sized hydropower stations. [Summary] [Beijing XINHUA Domestic Service in Chinese 23 Oct 85] /9604

SCIENTIFIC-TECHNOLOGICAL NEWSPAPER--Beijing, 31 Oct (XINHUA)--ZHONGGUO KEJI BAO [0022 0948 4430 2111 1032, CHINA SCIENTIFIC AND TECHNOLOGICAL NEWS], China's first nation-wide newspaper of its kind, will begin publication on New Year's Day, 1986. Deng Xiaoping wrote the title of the newspaper, which will report China's strategic decisions on its scientific and technological development, as well as progress in this field. The newspaper was jointly established by the State Science and Technology Commission, the Commission of Science, Technology and Industry for National Defense, and other units under the leadership of the State Council's Science and Technology Leading Group. It will be published three times a week. [Summary] [Beijing XINHUA Domestic Service in Chinese 0210 GMT 31 Oct 85] /9604

CHINA'S OLDEST SCIENCE JOURNAL--Beijing, 5 Nov (XINHUA)--Some scientists in Beijing gathered in a hall today to mark the 70th anniversary of KE XUE journal. At the meeting, Zhou Guangzhao read a letter of congratulation from Comrade Hu Qiaomu. Hu Qiaomu said in the letter: KE XUE journal is our oldest science journal which has made important contributions to and made profound impact on China's scientific undertakings. He hoped that KE XUE journal will make even more outstanding contributions in the future in reporting on new progresses and new problems in various scientific fields, on research findings of experts at home and on different academic views, and in promoting cooperation between scientists in China and in foreign countries. Some 100 scientists attended the meeting. They included Yan Jici, Zhou Peiyuan, Mao Yisheng, and Lu Jiaxi. [Excerpts] [Beijing XINHUA Domestic Service in Chinese 1434 GMT 5 Nov 85] /9604

CSO: 4008/1018



JPRS-CST-85-041  
10 December 1985

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TITLE: "Ion Exchange of Uranium. V. Uranium (IV) Species Sorbed on Anion Exchanger from Hydrochloric Acid"

SOURCE: Beijing HE HUAXUE YU FANGSHE HUAXUE [JOURNAL OF NUCLEAR AND RADIO-CHEMISTRY] in Chinese Vol 7 No 3, Aug 85 pp 135-140

TEXT OF ENGLISH ABSTRACT: Visible spectroscopy is used to study the  $U^{4+}$  cation and some complexes with  $Cl^-$  at high chlorine concentration. Infrared and visible spectroscopy are used to study the complexes of U(IV) with  $Cl^-$ -sorbed on anion exchange resin from the HCl solution. Experimental results seem to indicate that the predominant species sorbed on anion-exchange resin is  $UCl_6^{2-}$ . The dependence of the distribution ratio of U(IV) on the concentration of U(IV) in anion resin is in agreement with the assumption that the U(IV) species sorbed on anion resin is  $UCl_6^{2-}$ .

Chemistry

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ORG: Institute of Atomic Energy, Beijing

TITLE: "Studies of the Photochemistry of Uranyl Ion. III. Photochemical Reduction of U(VI) in  $U_2^{2+}$ -HCOOH- $HNO_3$  System with an Argon Ion Laser"

SOURCE: Beijing HE HUAXUE YU FANGSHE HUAXUE [JOURNAL OF NUCLEAR AND RADIO-CHEMISTRY] in Chinese Vol 7 No 3, Aug 85 pp 141-146, 154

TEXT OF ENGLISH ABSTRACT: The photochemical reduction of uranyl ion by formic acid is investigated using an argon ion laser at a wavelength of 4880 Å. The effects of concentration of the formic acid, formate, nitric acid, nitrate, uranyl ion and of temperature on quantum yield  $\Phi$  of U(IV) formed are studied. Experimental results indicate that U(VI) can be reduced photochemically to U(V), which disproportionates to U(IV) and U(VI).  $\Phi$  depends mainly on the degree of complex formation of uranyl formate  $\alpha$  in solution.  $\Phi$  increases with the increase of  $\alpha$ .  $\Phi$  reaches 0.5 when  $\alpha$  is close to 1. The rate of U(IV) formed is proportional to  $[HCOO^-]^{1.08}$  at low concentration of formate and to  $[UO_2^{2+}]^{1.01}$  at low concentration of uranyl ions respectively.

Chemistry

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CHEN Luonuo [7115 3157 1226]  
QIAN Hesheng [6929 0735 3932]

ORG: Shanghai Institute of Nuclear Research, Chinese Academy of Sciences

TITLE: "Study of the Extraction Mechanisms of Uranyl Nitrate and Thorium Nitrate by DMHMP"

SOURCE: Beijing HE HUAXUE YU FANGSHE HUAXUE [JOURNAL OF NUCLEAR AND RADIO-CHEMISTRY] in Chinese Vol 7 No 3, Aug 85 pp 147-154

TEXT OF ENGLISH ABSTRACT: In this paper the extraction mechanisms of uranyl nitrate and thorium nitrate by DMHMP are studied. The compositions of the extraction complexes are  $\text{UO}_2(\text{NO}_3)_2 \cdot 2\text{DMHMP}$  and  $\text{Th}(\text{NO}_3)_4 \cdot 3\text{DMHMP}$ . At a constant ionic strength  $\mu=2$ , the equilibrium constants for their formation are  $\lg K_U = 4.6$ ,  $\lg K_{Th} = 4.3$  respectively. The measured values of the distribution ratio of extraction agree quite well with those obtained by Leden's method.

Successive stability constants of the nitrate complexes of thorium by extraction with DMHMP are calculated by Leden's graphical method and via a least squares technique using a PDP11/70 computer. Both results agree well. The successive stability constants of the complexes formed are:  $\beta_1 = 8.0$ ,  $\beta_2 = 5.2$ ,  $\beta_3 = 0.8$ ,  $\beta_4 = 1.3$ . By comparison of equilibrium constant complex formation of DMHMP and TBP with U and Th, it can be expected that DMHMP will be superior to TBP for the extraction separation of uranium and thorium.

AUTHOR: TAO Zuyi [7118 4371 6318]  
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TITLE: "Kinetics of Shell-Progressive Reaction in Ion Exchange Resin.  
III. Ion Exchange Reaction Accompanying Chemical Interaction"

SOURCE: Beijing HE HUAXUE YU FANGSHE HUAXUE [JOURNAL OF NUCLEAR AND RADIO-  
CHEMISTRY] in Chinese Vol 7 No 3, Aug 85 pp 177-181

TEXT OF ENGLISH ABSTRACT: A general rate equation to predict the effect of combined film diffusion, intraparticle diffusion and chemical interaction on the rate of ion exchange reaction in a finite bath is derived. From this general rate equation, previous rate equations on ion exchange by a shell-progressive mechanism may be deduced. The rate of ion exchange is a function of  $\xi$  and  $\eta$ . From the parameters  $\xi$  and  $\eta$ , it is now possible to determine the circumstances prevailing in reactions in which one of these resistances is the rate determining step.

9717  
CSO: 4009/14

Computer Science

AUTHOR: LI Gansheng [2621 6373 3932]

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TITLE: "A Modular Programming Language--MC"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 1-12

ABSTRACT: This paper presents a programming language--MC, which is very suitable for writing system programs and application software. It is a variation of the programming language C. In a sense, MC is an extension of C. However, MC omitted some unnecessary feature of C, which are the main factors causing unreliability of C programs. MC also has the ability to support modular programming, separate compilation, and verification of programs. Its modules have clear interfaces with others. This paper gives a complete grammatical and semantic definition of MC.

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2. Niklaus Wirth, "Programming in Module-2," Springer-Verlag, 1983.

AUTHORS: YE Chengqing [0673 3397 3237]  
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TITLE: "Systematical Design of Syntax Analysis Procedure in Direct-execution High Level Language System"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 13-21

ABSTRACT: Direct execution of a high level language is a new execution mode. It has many advantages over editing, compilation, execution, and indirect executing modes in performance of interaction and debugging. However, there is no systematic design method for the direct execution system at present. This paper has developed a systematic design method for the direct execution system. With this method the syntax errors caused by any token can be detected and corrected at the program input stage. Therefore, direct execution system will achieve perfect performance in interaction, debugging, and error correction. This method has been used in the design of the syntax analysis procedure of a Micro COBOL direct execution system that has been implemented on a PDP-11/23 microcomputer.

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TITLE: "Principles and Methods of Color CAD"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 29-38

ABSTRACT: First, the paper analyzes the formula of shading techniques in current interactive computer graphics and shows some mistakes of the formula in display. Then, new formulas for correct display of diffuse illumination, reflected light, dark parts, and the sense of space are derived. These new formulas form the basis of real color display.

Second, the formulas that map Munsell system and Ostwald system to the RGB system of the color monitor are derived. Some methods using these systems to design coordination of colors are described.

Last, analysis of two examples of mixed materials and surface with color pattern shows the variety of ways of displaying color products.

Color pictures attached to the paper show the effect of the new formulas.

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TITLE: "Data Structures, Algorithms, and Program Structures of the Generation, Intersection, and Display of Curves and Surfaces"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 46-53

ABSTRACT: This paper, taking Bezier curves and surfaces as examples, studies the data structures, algorithms, and program structures in the processing of the interpolation, generation, intersection, and display of curves and surfaces based on the work of the Research Group of Computer Aided Airplane Contour Design.

A system designed according to these ideas is running with a satisfying result.

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A Theoretical Development for the Computer Generation and Display of Piece-wise Polynomial Surfaces, IEEE Transactions on Pattern Analysis and Machine Intelligence, 1980 PAMI-2, (1), PP 35-45.



AUTHORS: CHEN Zengwu [7115 1073 2976]  
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TITLE: "The Development of Chinese Information Processing System"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 63-74

ABSTRACT: From the viewpoint of system design, this paper, on development of Chinese information processing system in computers, puts forward some principles. The system should ensure Chinese-English compatibility. The processing of the input and output of Chinese characters should, in logic, be completed independently by I/O devices. Several internal codes of Chinese characters are also presented.

From the viewpoint of system function, this paper analyzes the difference between Chinese and English operating systems and the functions which a Chinese operating system must possess, as well as three software structures for implementing a Chinese character system. A multi-user, time-sharing Chinese information processing system is provided based on the above principles. Programming languages in Chinese are also discussed.

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操作系统结构 (UNIX操作系统)  
浙江大学教材。

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SOURCE: Zhejiang University

TITLE: "An Interactive Chinese Information Management System for the Sources of Energy"\*

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 86-92

ABSTRACT: A structural model of an interactive Chinese information management system for the energy sources in a paper manufactory is presented. This system is implemented by a micro Chinese character relational database language (C-DBASE II).<sup>1</sup> (\*This system passed provincial evaluation on 22 December 1984)

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TITLE: "H<sub>19</sub> Character and Graphics Intelligent Terminal"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 108-113

ABSTRACT: This paper describes a basic design principle of the H<sub>19</sub> character and graphics intelligent terminal which is an extension of the original H<sub>19</sub> character terminal with a graphics board. The timesharing and two-port frame buffer memory is used, therefore the contents of the dynamic RAM (4116-2 chips) can be reserved without refresh process. The standard RS-232 interface is used for interconnection, consequently the graphics board may be connected with any terminal and host computer which uses an RS-232 interface.

The terminal can display various graphics primitives such as point, solid line, dotted line, double dotted-dash line, circle, ellipse, and different size characters at eight directions. It offers rectangle drawing, area filling, and other graphics functions too. It features powerful functions, high reliability, compact structure, low cost, and is easy to operate. It is a graphics display device which can be used in broad application fields.

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ORG: Zhejiang University

TITLE: "An Automatic Routing System on Microcomputer"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 114-123

ABSTRACT: Presently, PCB automatic layout systems in China mainly use mini-computers. The system is expensive. So only a few institutes or big manufacturers can afford them. This paper describes a PCB automatic circuit layout system which is implemented on a microcomputer. The main features of the system are easy and flexible placement, faster and better routing with the use of a target-oriented search line method of testing obstacle shape, and a small amount of working storage by adopting rational link-list data structure. Such a system is suitable not only for one-layout printed circuit boards, but also two or multilayer PCB on a microcomputer.

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Computer Science

AUTHORS: XU Yuliang [1776 3022 5328]  
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TITLE: "The Microcomputer Based Online Identification and Control System"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 133-140

ABSTRACT: Using the least square method, a control algorithm with the objective function of a minimum variance has been developed which can be used to carry out online identification and real-time control for a system whose mathematical model is unknown. The paper illustrates an example of an electric furnace. The organization, software and experimental results of the system are presented.

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AUTHOR: HU Ximing [5170 1585 2494]

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TITLE: "The UNIX Program Running Environment"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 141-145

ABSTRACT: An integrated analysis is presented on the program running environment of the UNIX time-sharing system from the point of view of process. It is hoped that by the aid of this paper, a better understanding of the UNIX programming environment and a better use of the UNIX source can be achieved.

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Computer Science

AUTHOR: JIN Tingzan [6855 1694 6363]  
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TITLE: "Arrangement and Generation for Permutation and Combination"  
SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 146-160

ABSTRACT: Permutation and combination is a fundamental topic in discrete mathematics. As is well known, the number of distinct permutations for  $n$ -objects is  $n!$ , and the number of distinct combinations selecting  $k$  objects from  $n$ -objects is  $\binom{n}{k}$ . It is not difficult to generate all permutations or combinations sequentially in certain order. But only to generate a special (but any) permutation or combination is not easy! This paper discusses some methods for arranging permutation or combination, then solving the above problem.

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Combinatorial Algorithms: Theory and practice 1977.
- [2] ALBERT NIJENHUIS and HERBERT S. WILF  
Combinatorial Algorithms For Computers and calculators 1978.
- [3] RICHARD A. BRUALDI  
Introductory Combinatorics 1977.
- [4] DANIEL I.A.COHEN  
Basic Techniques Of Combinatorial Theory 1978.

Computer Science

AUTHOR: JIN Tingzan [6855 1694 6363]

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TITLE: "Arrangement and Generation for Permutation and Combination About a Countable Aggregate"

SOURCE: Hangzhou ZHEJIANG DAXUE XUEBAO (ZENGKAN) [JOURNAL OF ZHEJIANG UNIVERSITY (SUPPLEMENT)] in Chinese "Special Issue on Computers" 25 Jul 85 pp 161-167

ABSTRACT: On the basis of the previous paper in this issue, "Arranging and Generating for Permutation and Combination," this paper discusses and solves the same problem about a countable aggregate.

REFERENCES:

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Combinatorial Algorithms: Theory and practice 1977.
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Combinatorial Algorithms For Computers and calculators 1978.
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CSO: 4009/1021

Computer Science

AUTHOR: LU Hanrong [7627 3352 2827]  
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TITLE: "A Distributed Algorithm for an Optimal Task-scheduling Problem"  
SOURCE: Chongqing CHONGQING DAXUE XUEBAO [JOURNAL OF CHONGQING UNIVERSITY]  
in Chinese Vol 8 No 3, Sep 85 pp 62-68

ABSTRACT: The general task scheduling problem is NP hard and usually, a heuristic algorithm of polynomial time complexity is adopted. An optimal-scheduling problem is first presented, then, an effective distributed algorithm to solve the problem is proposed. Finally, based on simulation and analysis, the algorithm's behavior is informally discussed. (Paper received 8 November 1984.)

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CSO: 4009/1022

Physics

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TITLE: "Bifurcation Diagrams in Liquid Crystal Hybrid Optical Bistability"

SOURCE: Beijing WULI XUEBAO [ACTA PHYSICA SINICA] in Chinese Vol 34 No 8,  
Aug 85 pp 992-999

ABSTRACT: In this paper we report the calculation results of bifurcation diagrams in liquid crystal (LC) hybrid optical bistability. The  $x$ - $A$  and  $x$ - $x_B$  bifurcation diagrams and the  $A$ - $x_B$  phase portrait are given. The symmetry of the bifurcation diagram, the sudden change and hysteresis phenomena of chaotic regions and the effect on the structure of chaotic regions caused by LC transmittance function with two peaks are observed.

# Physics

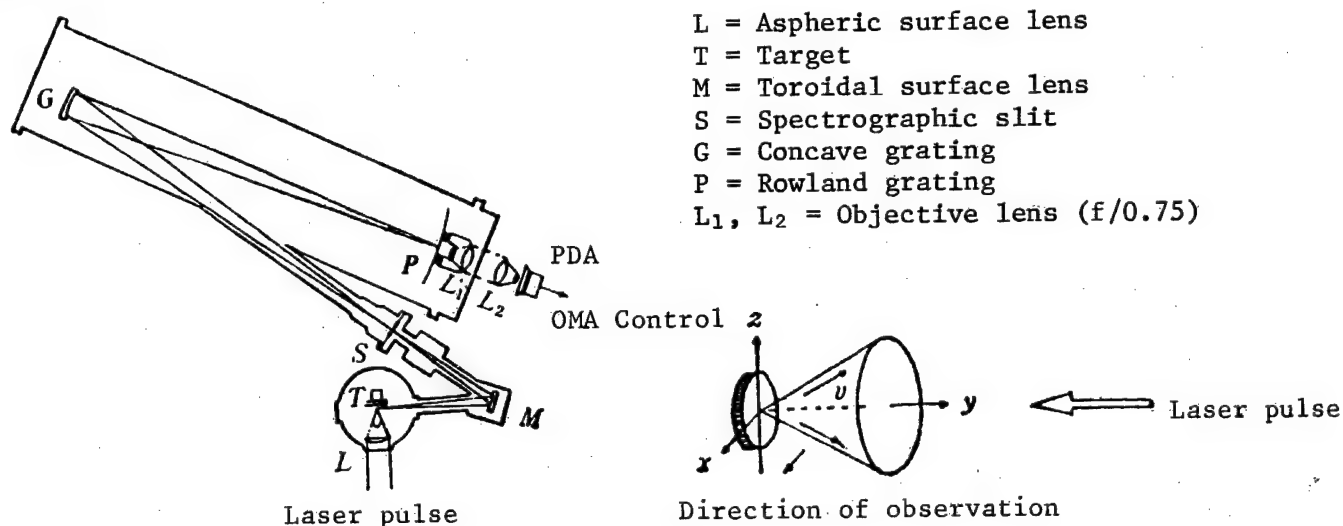
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TITLE: "Spectroscopic Observations of the Line Stark Broadening in the  
Ultraviolet Vacuum in Laser-produced Plasmas"

SOURCE: Beijing WULI XUEBAO [ACTA PHYSICA SINICA] in Chinese Vol 34 No 8,  
Aug 85 pp 1049-1055

ABSTRACT: The emission from dense plasmas produced by a Q-switched ruby laser pulse focusing on plane targets of the elements Be, C, and N has been observed in an ultraviolet vacuum at various distances from the target surface. For recording the emission spectra an intensified photodiode array and an optical multichannel analyzer have been implemented. Very broad lines of the type  $\Delta n = 1$  of the H-like, He-like, and Li-like ions arising from the relatively high principal quantum number  $n$  appear prominent in the spectra. According to the ion quasistatic approximation theory, the electron densities of the plasmas as the function of the distances from the target surface have been derived.



Physics

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TITLE: "Hydrostatic Pressure Dependence of Gold Acceptor Levels in Si"

SOURCE: Beijing WULI XUEBAO [ACTA PHYSICA SINICA] in Chinese Vol 34 No 8, Aug 85 pp 1068-1074

ABSTRACT: The hydrostatic pressure coefficient of gold acceptor levels  $E_T$  in silicon was measured by the transient capacitance method. Under the pressure range of 0-8 kbar, the pressure coefficient  $\partial(E_C - E_T)/\partial P = -1.9$  meV/kbar. The electron capture cross section of gold acceptor centers does not depend on the pressure within the experimental accuracy. By comparing the present results of the hydrostatic pressure coefficient with the uniaxial pressure coefficient, we conclude that the defect potential is lacking  $T_d$  symmetry. Therefore, the gold acceptor levels do not originate from simple gold substitutional or interstitial configurations in Si crystals.

Physics

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TITLE: "A Bistable InGaAsP/InP DH Laser With Internal Modulation on Q  
Factor Formed by Proton Bombardment"

SOURCE: Beijing WULI XUEBAO [ACTA PHYSICA SINICA] in Chinese Vol 34 No 8,  
Aug 85 pp 1102-1106

ABSTRACT: This article reports a new type of InGaAsP/InP bistable DH laser (BSDH) formed by proton bombardment with internal modulation on the Q factor. The typical bistability exhibited in the L-I curve in these BSDH's has been obtained. The current range of bistable operations is 50 mA to 200 mA, measured in two samples. The value can be varied by selecting the device parameters. It is very interesting that the laser light emitted from the BSDH operating with various injection currents has a high stable single longitudinal mode. The peak wavelength is 1.2596  $\mu\text{m}$  and the stability on the wavelength is about  $10^{-5}$ . In addition, a qualitative discussion is presented.

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CSO: 4009/1

Physics

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TITLE: "New Methods on Determination of Gyromagnetic Ratio of Proton  $\gamma_p'$ "

SOURCE: Chongqing CHONGQING DAXUE XUEBAO [JOURNAL OF CHONGQING UNIVERSITY]  
in Chinese Vol 8 No 3, Sep 85 pp 148-154

ABSTRACT: Basic concepts, principles, and several new methods used in measurements in recent years on determination of gyromagnetic ratio of proton  $\gamma_p'$  are described in detail. Measurement techniques concerning with dimensions of precisions of precision solenoid are emphasized. The author was engaged in research on the determination of gyromagnetic ratio of proton  $\gamma_p'$  in the National Bureau of Standards, United States, from July 1982 to September 1984, the current research status concerning this project in the United States is briefly introduced. (Paper received 14 December 1984)

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